5-3895-287-15

TM 5-3895-287-15

DEPARTMENT OF THE ARMY TECHNICAL MANUAL

OPERATOR, ORGANIZATIONAL
DIRECT SUPPORT, GENERAL SUPPORT
AND DEPOT MAINTENANCE MANUAL

MIXER, BITUMINOUS MATERIAL
NON-SELF-LOADING, DIESEL ENGINE DRIVEN
(BARBER-GREENE MODEL KA-60)
FSN 3895-933-0577
WITH ELEVATOR, BUCKET TYPE
(BARBER-GREENE MODEL 882-251)
FSN 3910-089-9357
COMPONENTS OF MIXING PLANT, ASPHALT
100-150 TON PER HOUR, MDL KA-60
FSN 3895-936-8613

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HEADQUARTERS, DEPARTMENT OF THE ARMY
APRIL 1968

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C 1

CHANGE No. 1

HEADQUARTERS
DEPARTMENT OF THE ARMY
WASHINGTON, D.C., *19 June 1973*

Operator, Organizational, Direct Support, General Support, and Depot Maintenance Manual MIXER, BITUMINOUS MATERIAL, NONSELF-LOADING, DIESEL ENGINE DRIVEN, (BARBER-GREENE MODEL KA-60) FSN 3895-933-0577, WITH ELEVATOR, BUCKET TYPE (BARBER-GREENE MODEL 882-251) FSN 3910-089-9367 COMPONENT OF MIXING PLANT, ASPHALT, 100-150 TON PER HOUR, MDL KA-60, FSN 3895-936-8613

TM 5-3895-287-15, 30 April 1968, is changed as follows:
Appendix A is superseded as follows:

APPENDIX A

BASIC ISSUE-ITEMS-LIST-AND ITEMS TROOP INSTALLED OR AUTHORIZED LIST

Section I. INTRODUCTION

1. Scope

This appendix lists items required by the operator for operation of the mixer and elevator.

2. General

This list is divided into the following sections:

a. Basic Issue Items List—Section II. Not applicable.

b. Items Troop Installed or Authorized List—Section III. A list of items in alphabetical sequence, which at the discretion of the unit commander may accompany the mixer and elevator. These items are not subject to turn-in with the mixer and elevator when evacuated.

3. Explanation of Columns

The following provides an explanation of columns in the tabular list of items troop installed or authorized, section III.

a. Source, Maintenance and Recoverability Code(s) (SMR): Not applicable.

b. Federal Stock Number. This column indicates the Federal stock number assigned to the item which will be used for requisitioning purposes.

c. Description. This column indicates the Federal item name and any additional description of the item required.

d. Unit of Measure (U/M). A two-character alphabetic abbreviation indicating the amount or quantity of the item upon which the allowances are based; e.g., ft, ea, pr; etc.

e. Quantity Authorized

This column indicates the quantity of the item authorized to be used with the equipment.

Section III. ITEMS TROOP INSTALLED OR AUTHORIZED LIST

(1) *SMR code*	(2) *Federal stock number*	(3) *Description*	(4) *Unit of meas*	(5) *Qty auth*
	4210-889-2221	Extinguisher, Fire	ea	1

By the Order of the Secretary of the Army:

CREIGHTON W. ABRAMS
General, United States Army
Chief of Staff

Official:
VERNE L. BOWERS
Major General, United States Army
The Adjutant General

Distribution:

To be distributed in accordance with DA Form 12-25B (qty rqr block No. 914), Organizational Maintenance Requirements for Mixer, Bituminous.

SAFETY PRECAUTIONS

BEFORE OPERATION

Replace all machinery guards immediately after lubrication or adjustment.

Be sure electrical power is shut off before working on any electrical components.

Follow all lubrication and preventive maintenance procedures with care to avoid damage to the equipment.

Do not smoke or use an open flame in the vicinity when servicing the batteries. Batteries generate hydrogen, a highly explosive gas.

Do not overfill a battery or splash electrolyte. Spilled electrolyte will cause personal injury or equipment damage.

When filling the fuel tank, always provide metal-to-metal contact between the container and the fuel tank. This will prevent a spark from being generated as fuel flows over the metallic surfaces.

Always correct or report any mechanical deficiencies that may in damage to the mixer if operated.

Do not place tools or rags near working parts.

Make sure the brakes are set with the parking brake lever when the mixer is parked.

DURING OPERATION

Never attempt to clean, oil, adjust, or perform any maintenance while the mixer is in operation.

Do not engage the starting motor for more than 30 seconds at a time without allowing a 3 minute cooling-off period.

Do not run the water pump more than 2 or 3 minutes with all the valves in the discharge line closed.

When introducing steam into a cold line, open the valve very slowly to allow the piping and jackets to heat up gradually.

When starting the transfer or metering pumps, engage the clutch slowly. Do not continue to "slip" the clutch if pump fails to turn over, as this will cause the clutch to heat.

Be sure to close water control valve when pumping between all temperatures higher than 212°F., to prevent the heat of the pumps from causing the water in the engine cooling system to boil.

Do not stand near open rotating drive chains and sprockets.

Never put full speed or load on a cold engine.

Shut off engine before making repairs or adjustments on the mixer.

Be sure all machinery guards are in place.

AFTER OPERATION

Shut the pressure off to any line, fitting, or valve before loosening the connections.

Be sure electrical power is shut off before working on any of the electrical components.

When filling the fuel tank, always provide metal-to-metal contact between the container and the fuel tank. This will prevent a spark from being generated as fuel flows over the metallic surfaces.

Do not smoke or use an open flame in the vicinity when servicing the batteries. Batteries generate hydrogen, a highly explosive gas.

Do not overfill a battery or splash electrolyte. Spilled electrolyte will cause personal injury or equipment damage.

Always correct or report any mechanical deficiencies that may result in further damage to the mixer if operation is continued.

Follow all lubrication and preventive maintenance procedures with care to avoid damaging the equipment.

Do not place tools or rags near working parts.

Make sure the brakes are set with the parking brake lever when the mixer is parked.

Be sure the fire extinguisher is in place and in operating condition.

TECHNICAL MANUAL

TM 5-3895-287-15

HEADQUARTERS
DEPARTMENT OF THE ARMY
WASHINGTON D.C. 30 APRIL 1968

NO. 5-3895-287-15

OPERATOR, ORGANIZATIONAL, DIRECT SUPPORT, GENERAL SUPPORT, AND DEPOT MAINTENANCE MANUAL

MIXER, BITUMINOUS MATERIAL, NON-SELF-LOADING, DIESEL ENGINE DRIVEN, (BARBER-GREEN MODEL KA-60) FSN 3895-933-0577, WITH ELEVATOR, BUCKET TYPE, (BARBER-GREEN MODEL 882-251) FSN 3910-089-9357.

COMPONENTS OF MIXING PLANT, ASPHALT, 100-150 TON PER HOUR, MDL KA-60, FSN 3895-936-8613

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PART I

MIXER AND ELEVATOR

RECEIVING MACHINE

Section A

Your Barber-Greene Mixer was thoroughly tested, carefully inspected, and properly loaded at the factory. The entire shipment including loose parts was thoroughly checked before it was released to the transportation company.

Upon receipt of the machine, before unloading, carefully inspect for any loss or damage that may have occurred during transportation. It would be well to check it against your freight bill, or against the packing list which will be found in the tool box.

If any loss or damage is discovered, you will save time by immediately notifying the transportation company's agent who will give you the proper forms for making a claim.

***DO NOT START THE ENGINE** until you have read and understand the section on starting procedure – Page E-1.*

*For **UNLOADING INSTRUCTIONS** refer to Page A-2.*

SAFETY FIRST

Most accidents are caused by someone's failure to follow simple and fundamental safety rules or precautions.

Regardless of the care used in the design and construction of machinery, there are many points that cannot be completely safeguarded without interfering with accessibility and efficient operation.

A careful operator is the best insurance against an accident.

THE COMPLETE OBSERVANCE OF ONE SIMPLE RULE WOULD PREVENT MANY THOUSAND SERIOUS ACCIDENTS EACH YEAR.

THAT RULE IS:

Never Attempt To Clean, Oil, or Adjust any Machine While it is in Motion

To insure accuracy when ordering parts or requesting service information, always refer to your machine serial number.

The serial number plate is located on the main frame upper section on the operator's side of the mixer.

UNLOADING MACHINE

(Remove all wires, bands and blocking)

BY CRANE

The best and easiest method to unload the Mixer is by overhead crane if one is available. *(Refer to Specifications, Section B, for weight of your Mixer.)*

The Mixer is provided with lifting rings welded to the machine structural for convenient hook-up of cables or chains. Note Lifting Diagram below.

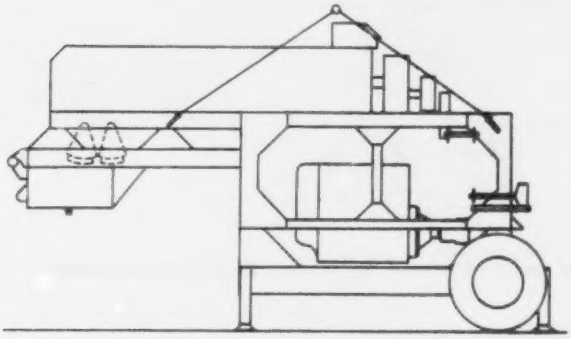


Figure A-1. Lifting Diagram

TO PLATFORM

If no crane is available and the Mixer is to be unloaded onto a platform, the platform must be able to support the weight of the machine.

Spot the car so the machine can be maneuvered around and the gap between car and platform bridged over with timber suitable to support the machine weight.

Using a truck or tractor, turn the machine around so the towing tongue can be attached and tow the machine from the car onto the platform.

BY INCLINED RAMP

If an inclined ramp is used at the end of the car, a truck or tractor can be used to tow the Mixer down the ramp.

Extreme caution should be used in going down the ramp. If the Mixer is equipped with brakes they can be used to control the speed of descent.

A snubbing line attached to the rear of the main frame to prevent the Mixer from getting away is always a good safety measure to use.

BY TEMPORARY RAMP

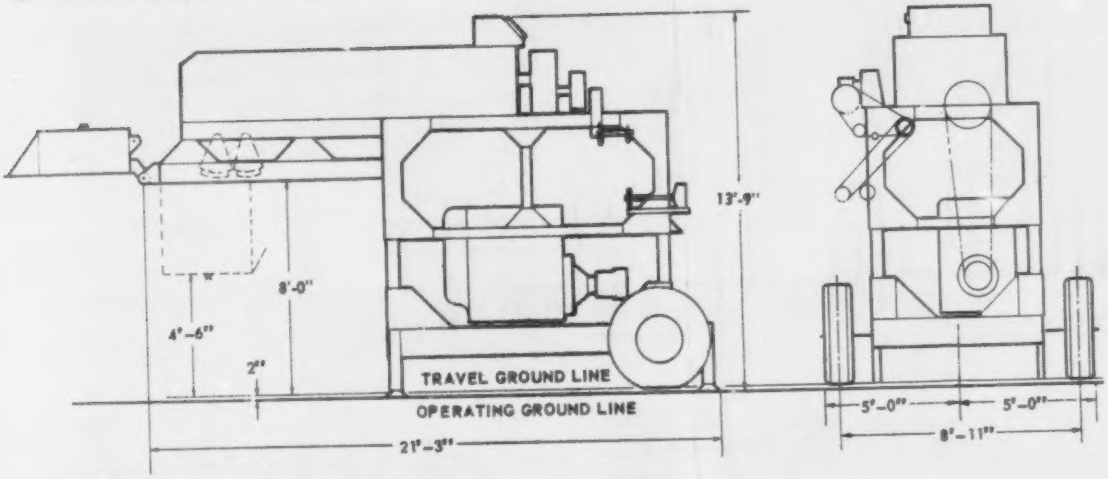
If no ramp or platform is available a temporary ramp will have to be built.

It should be carefully planned and constructed. It should be of sufficient width and length to provide ample clearance for the Mixer, also of sufficient strength to support the combined weight of the machine and a truck or tractor used to tow machine down the ramp.

Here again a snubbing line attached to the rear of the Mixer to prevent it from "getting away", should be used.

SPECIFICATIONS

Continuous Asphalt Mixer Model KA-60



CAPACITY:

115 to over 195 TPH depending on mix design, aggregate characteristics, and asphalt viscosity. (With mix level at mid-point of paddle arms, 154 TPH @ 45 seconds mix time, 198 TPH @ 35 seconds).

WEIGHT:

25,500 Lbs. (total)

Rear Axle Load	14,500 Lbs.

OVERALL DIMENSIONS:

Towing Height	11'-9½"
Operating Height — Without Stack	13'-9"
Width	10'-0"
Length	21'-3"
Discharge Height	8'-0"

POWER UNIT:

105 HP International model UD-14A diesel engine, operating 85 HP @ 1800 RPM, 4 cylinders, 4-¾ bore x 6-½" stroke, 461 Cu. In. displacement, with SAE #1 bell housing, 12 volt electric starter and generator, voltage regulator, two 6-volt batteries, oil bath air cleaner, oil filter and push button electric throttle control.

TRANSMISSION AND MACHINERY:

Totally enclosed main gear box with cut tooth gears running in oil. Shaft mounted torque arm speed reducer with cut tooth gears running in oil, driven by V-belts from engine or electric motor. Centrifugal type master clutch. Auxiliary drives from main gear box through roller chain and cut tooth sprockets and line shafting.

CHASSIS:

Heavy structural steel made in two parts. Lower frame contains wheels and axle, fuel tank and power unit. Upper frame contains pugmill, pumps and asphalt piping. Upper frame, when raised to operating level, is supported on heavy pipe columns.

RUNNING GEAR:

Single rear axle with single pneumatic 13:00 x 20" tires.

BRAKES:

17" x 4" hydraulic brakes with air controls through an air-over-hydraulic conversion cylinder.

PUGMILL:

8'0" long, 2'8" deep, and 3'10" wide. Replaceable ¾" Ni-hard liners; paddle shafts are 4½" square, high carbon steel. Paddle tips are Ni-hard cast iron, reversible, replaceable and adjustable. Mill is jacketed for heating with steam or hot oil. Pugmill is covered and equipped with exhaust stack to keep fumes above mixer.

ASPHALT SYSTEM FOR KA-60 ONLY:

Asphalt circulated continuously at 67 GPM by 2½" transfer pump. Dial controlled 2" variable volume positive displacement asphalt metering pump, capacity up to 42 GPM. All asphalt lines jacketed for heating with steam or hot oil.

PUGMILL DISCHARGE HOPPER:

Hydraulically operated, covered, approximately 1½ ton capacity, operator controlled. Discharge hopper-full telltale.

HYDRAULIC SYSTEM FOR KA-60 ONLY:

Compact hydraulic system on Mixer, driven from torque arm gear box. For hydraulic discharge hopper only.

FINES FEED SYSTEMS:

For bag or bulk type. Refer to gradation unit specification sheet.

TOOLS:

Two 8-ton hydraulic jacks.

LUBRICATION:

High pressure hydraulic Alemite.

GENERAL DESCRIPTION

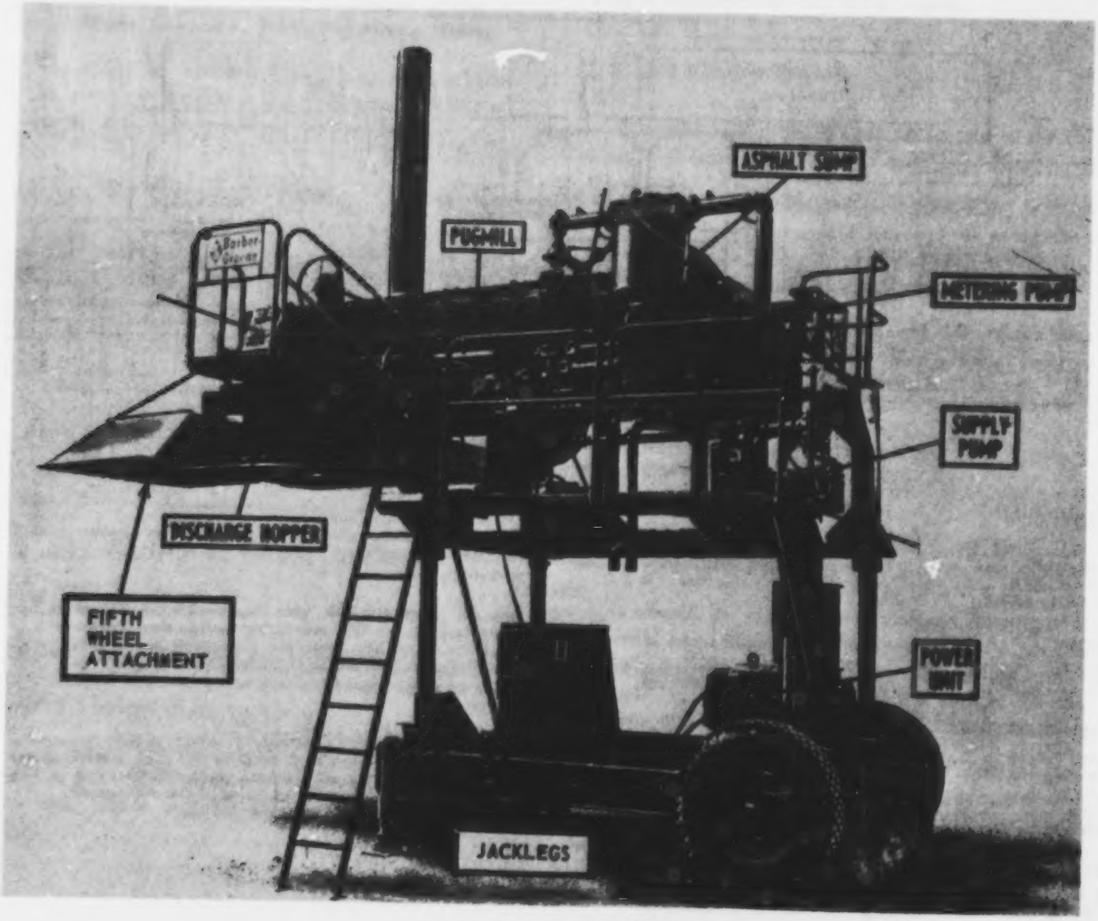


Figure B-1. **KA-60 Mixer.** 463-874

The KA-60 Mixers consist of two sub units mounted on a single frame. The upper section consists of the pugmill, metering pump, supply pump, and asphalt piping. The lower section contains the power unit, wheels and axle, and fuel tank.

PUGMILL *(Refer to Figure B-1.)*

The mixing action of the pugmill is produced by twin paddle shafts revolving in opposite directions. Each shaft is fitted with 16 paddle arms. Paddle tips are bolted to each paddle arm at an angle so that as the paddles revolve, each paddle forces a small portion of the mix toward the discharge end of the pugmill. In this manner the material is moved in a continuous flow through the pugmill. An adjustable dam gate at the discharge end controls the mixing time.

PUGMILL DISCHARGE HOPPER *(Refer to Figure B-1.)*

The pugmill discharge hopper permits surge storage and control of aggregate segregation. The double clamshell type gates open and close hydraulically. Discharge is controlled manually on standard machines. Automatic discharge is optional.

METERING PUMP *(Refer to Figure B-1.)*

The variable volume metering pump supplies asphalt in a metered flow to the spray bar. The pump is of the positive displacement type.

The pump capacity is variable, and is changed by turning the dial on the face of the pump.

The pump is driven from a shaft that is mechanically interlocked with the shaft that drives the 882 Hot Elevator and Gradation Control Unit, so that percentage of bitumen to aggregate remains constant. The pump will handle all asphalts and emulsions, provided the asphalts are heated sufficiently.

SPRAY CHAMBER

As the aggregate discharges from the hot elevator, it is sprayed with a film of asphalt from the spray bar in the spray chamber.

The spray bar is equipped with nozzles that form the discharging asphalt into a fan-shaped spray, coating a large portion of the surface area of the aggregate with asphalt before entering the pugmill.

POWER UNIT *(Refer to Figure B-1.)*

The power unit drives the pugmill through the pugmill gear box. **The master clutch engaged the pugmill gear box.**

RUNNING GEAR *(Refer to Figure B-1.)*

A single axle with single pneumatic tires is used as running gear for the mixer. Hydraulic brakes are used with operating air pressure supplied by the prime mover.

JACKLEGS *(Refer to Figure B-1.)*

The four screw type jacklegs supplied with the mixer have swivel base joint connectors to compensate for base irregularities.

HYDRAULIC EQUIPMENT

The hydraulic system operates the hopper gate on the mixer.

Power to operate the system is supplied by the pugmill gearbox driving a vane type, constant delivery, hydraulic pump.

SUPPLY PUMP *(Refer to Figure B-1.)*

The steam or oil jacketed rotary type supply pump draws asphalt from the storage tank and provides a positive head to the metering pump. The supply pump is driven from the same shaft that drives the metering pump.

882 HOT ELEVATOR (Optional)

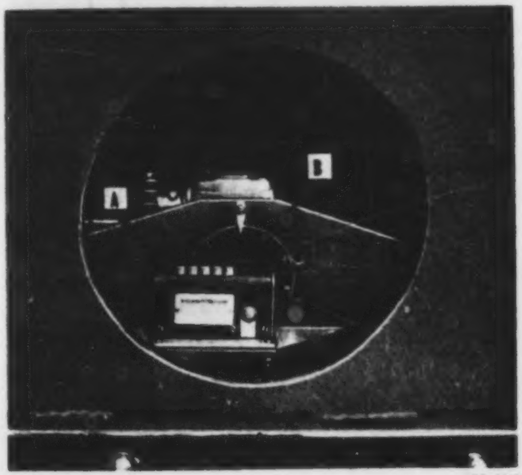
The hot elevator transfers the aggregate from the Gradation Control Unit to the Mixer pugmill. The elevator is driven by the Mixer.

REVOLUTION COUNTER *(Refer to Figure B-2.)*

A revolution counter is installed on the KA Series mixers to totalize the number of revolutions turned by the master reference shaft.

On KA series mixers, the counter is used in the calibration of the mixer, gradation unit, and fines feeder.

The counter (A) registers full revolutions, and the circular dial with the pointer (B) registers the tenths and hundredths of a revolution.



463-562

Figure B-2. Revolution Counter

USE OF CONTROLS **Section C**

Read this section carefully before operating mixer.

POWER UNIT

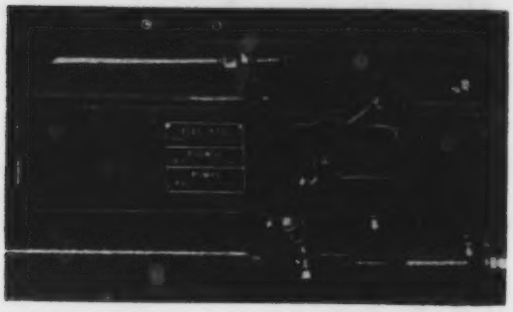
There are important differences between various types of power units; therefore, before starting power unit, read the Engine Manufacturer's Manual furnished in addition to this manual.

MASTER CLUTCH

The master clutch is factory set.
TO ENGAGE: Push lever away from operator.
TO DISENGAGE: Pull lever back toward operator.

NOTE-On electric drive mixers, the motor is started and stopped to operate the master clutch.

The **master** clutch permits the mixer, hot elevator, and gradation unit to be stopped and started quickly and without emptying the pugmill.



463-484

Figure C-1. Clutch Levers

CLUTCH LEVERS *(Refer to Figure C-1.)*

Mounted next to the three clutch levers is an instruction plate indicating the direction each lever is moved to engage or disengage the clutches.

WARNING-DO NOT MOVE THESE LEVERS WHEN MASTER CLUTCH IS ENGAGED.

ELEVATOR PTO CLUTCH

This jaw clutch controls the Hot Elevator and the Gradation Control Unit.

PUGMILL CLUTCH

This clutch, located inside the main gear box, controls the pugmill paddle shafts only.

PUMP CLUTCH

This jaw clutch controls the metering pump and the supply pump.

Figure C-2. Not applicable.

PUGMILL DAM GATE CONTROL WHEEL

(Refer to Figure C-3.)

To dam the flow of discharging material from the pugmill, turn hand wheel to raise dam gate.

A lock is provided for holding the wheel in any position desired.

To reduce resistance of material to discharge, turn wheel to lower dam.

PUGMILL DISCHARGE HOPPER CONTROL

MANUAL

This is a push-pull type hydraulic valve located to the right of the dam gate control wheel on the pugmill.

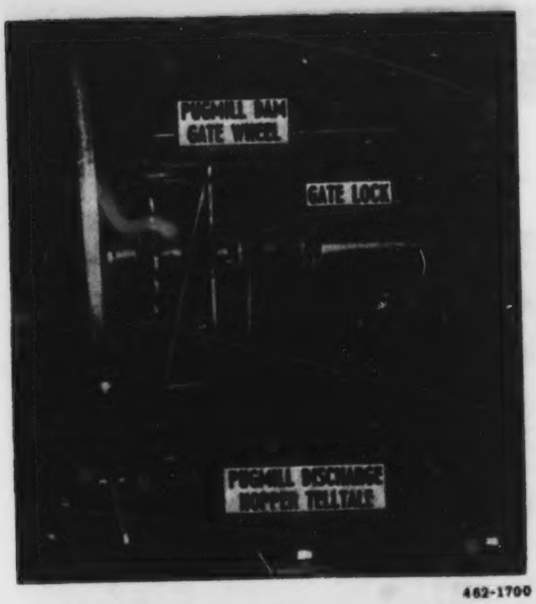


Figure C-3. Pugmill Dam Control Wheel

Figure C-4. Not applicable.

PUGMILL DISCHARGE HOPPER TELLTALE *(Refer to Figure C-3.)*

Located on the discharge hopper is a telltale to indicate to the operator how much material is in the discharge hopper. When the telltale is in a vertical position, the hopper is empty, and when it is in a horizontal position the hopper is full.

On manual machines, the operator should use the telltale as a guide to indicate that the hopper is ready to be discharged when the telltale is horizontal.

On automatic machines, the telltale operates a cutoff to stop the mixer should a failure in the mixing cycle cause material to build up too high in the hopper. If this occurs, switch to manual hopper dump, press hopper dump button, and hold mixer start button in until hopper gate opens. Correct cause of failure before continuing operation.

SELECTION OF PLANT SITE

An item of considerable importance to efficient plant operation is the selection of a practical plant site. A hasty selection of the plant site, without giving consideration to the various factors involved, will result in many complicating problems later on, at a time when it is impossible to improve the situation without resetting the plant.

NOTE: *Maximum towing speed is 20 MPH for Mixer.*

Consideration must be given to the following:

1. Ground area needed for the plant layout, *(Refer to Field Erection Drawings furnished with your plant.)*

   NOTE-*In addition to the dimensions shown in these drawings, the plant site must be adequately large to provide room for stockpile storage, asphalt supply tanks, fuel storage tanks, boiler or hot oil heater, truck scales, inspectors shack and tool shed. Room must also be provided for unrestricted movement of trucks hauling material to and from the plant.*
2. Stability of the ground in the plant area, since a pit may have to be excavated for the Cold Elevator and Feeder used with the Dryer.
3. Contour of the ground, since each machine when erected must be set on the same plane of elevation.
4. Drainage of the plant site to provide drainage for ordinary rainfall.
5. Prevailing winds should be considered when orienting the plant, and in determining nuisance effect of dust and smoke on neighboring property.

HOT ELEVATOR ERECTION

In the multiple aggregate plant set-up, normally the Gradation Control Unit is the first machine erected. *(Refer to Gradation Control Unit OSM.)*

After the Gradation Control Unit has been moved into place and raised to operating position, the Mixer Hot Elevator is erected.

MIXER ERECTION *(Refer to Figures D-1 through D-4.)*

The mixer is raised to operating position by hydraulic jacks furnished with the mixer.

1. Level the ground area, lay out machine center lines and lay foundation planks.

463-883

Figure D-1. Towing Attachment

463-442

Figure D-2. Jackleg

2. Tow mixer into position over center line and move towing attachment to operating position by removing bolts (A) and attaching hooks (B). *(Refer to Figure D-1.)*
3. Lower jacklegs. *(Refer to Figure D-2.)*
4. Raise machine enough to give wheels ground clearance. About 2 inches.
5. Remove bolts holding upper section to lower section and loosen bolts on locking clamps. Disconnect air brake line on mixer *(Refer to Figure D-3.)*

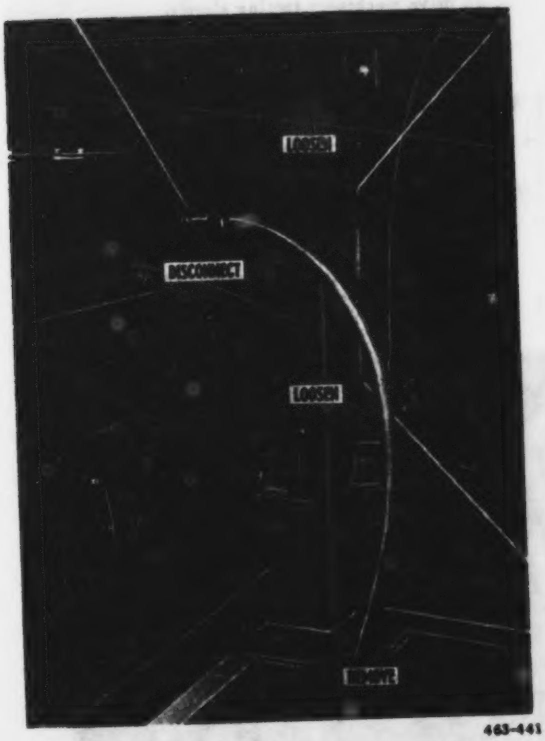


Figure D-3. Section Disconnection

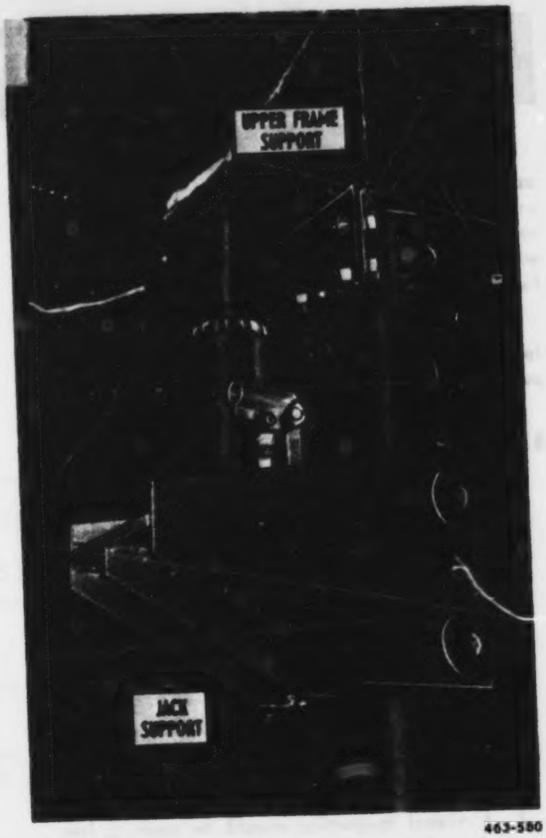


Figure D-4. Hydraulic Jack

6. Place hydraulic jacks in position. Jack up the upper section about 6 inches and install upper section locking braces. Raise the upper section one set of holes at a time, moving jack supports up one set of holes each time a lift is made to provide reach for the jacks. *(Refer to Figure D-4.)*
7. Attach drive V-belts. Tighten bolts on locking clamps. Install master clutch guard.
8. After the upper section has been raised to the desired height, check the level of the mixer frame both transversely and longitudinally. Unscrew jacklegs as needed to level mixer.
9. Install walkways, handrails, and ladder.
10. Raise pugmill exhaust stack.
11. Attach elevator discharge chute and install canvas boot and bands.

RAISING MIXER

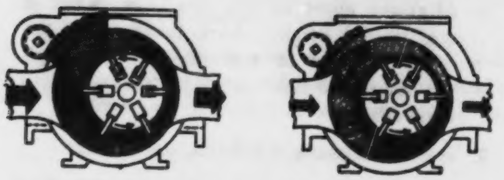
1st Lift 1'-2"
2nd Lift 7"

After the complete plant has been erected and all units readied for operation, (for Gradation Unit erection, refer to Gradation Unit OSM; for Dryer erection, refer to Dryer OSM), operate the equipment without asphalt or steam and check all moving parts for binding, alignment, etc.

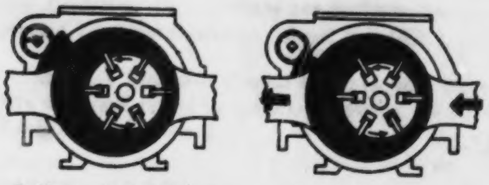
***IMPORTANT**-Do not operate asphalt pumps for any length of time without asphalt in them or pumps may overheat and be damaged.*

BEFORE STARTING ENGINE

1. Consult Engine Operator's Manual furnished in addition to this manual for checking out power unit.
2. Check oil level in main gear box and speed reducer gear box. *(Referto Lubrication Section F.)*
3. Check oil level in hydraulic oil tank. *(Refer to Lubrication Section F.)* Open accumulator valve.
4. Check oil level in Hot Elevator gear boxes. *(Refer to Lubrication Section F.)*
5. A visual inspection should be made to see that all grease points have been lubricated and that Mixer is ready for operation. It is not necessary to completely relubricate the Mixer as over-greasing distorts and blows seals on the anti-friction bearings. *(Refer to Lubrication Section F.)*



1. Full Forward Flow 2. Partial Forward Flow



3. Neutral – No Flow 4. Reverse Flow

Figure E-1. Metering Pump Flow

STARTING MIXER

1. Start engine, *(For instructions refer to Engine Operator's Manual Furnished in Addition to this Manual)*, and allow to run at idle speed.
2. Engage clutch levers *(Refer to Use of Controls Section C.)* (For Dryer Operation Refer to Dryer OSM.) Increase Engine Speed to start all drive machinery turning slowly.

   ***NOTE:** Clutch levers must be engaged with master clutch disengaged.*
3. A thorough inspection should be made of all drives on each unit to see that everything operates properly.
5. Slowly open power unit throttles until machines are running at full operating speed. Allow plant to run at operating speed for 2 or 3 minutes. If each unit is operating satisfactorily the plant is ready to be calibrated.

463-361

Figure E-2. Metering Pump

SETTING THE ASPHALT METERING PUMP *(Refer to Figures E-1 through E-3.)*

The asphalt metering pump is adjusted by means of the dial shaft on the pump.

1. Determine the tons per hour of asphalt required from the mix formula (Example - 200 TPH with 6% asphalt = 12 TPH of asphalt.)
2. The reference shaft speed was chosen to simplify pump setting. If one pound of asphalt is delivered for one revolution of the revolution counter, the asphalt is being delivered at the rate of one ton per hour.

KA-KB-70

METERING PUMP CAPACITY CHART

Pump Setting	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
Lbs. Per Rev.	4.8	6.0	7.2	8.4	9.6	10.8	12.0	13.2	14.4	15.6	16.8	18.0	19.2	20.4	21.6	22.8	24.0

NOTE: Lock Pump Liner after adjustment with lock screw in face of pump and dial lock.

Chart is based on asphalt at 7.85 Lb. per gallon.

KA-KB-60

METERING PUMP CAPACITY CHART

Pump Setting	20	30	40	50	60	70	80	90	100
Lbs. Per Rev.	3.34	5.0	6.67	8.34	9.72	11.8	13.2	15.3	16.7

NOTE: Lock Pump Liner after adjustment with lock screw in face of pump and with dial lock.

Chart is based on asphalt at 7.85 lb. per gallon.

Figure E-3. Metering Pump Capacity Charts

3. Set the pump dial to the desired setting to give the pounds per revolution (=TPH) required in the mix by:
   a. Loosening the lock bolt on the pump head and the set screw on the dial shaft *(Refer to Figure E-2.)*
   b. Adjusting the dial setting according to metering pump capacity charts (Refer to Figure E-3.) Chart is based on asphalt weighing 7.85 lbs. per gallon.

   ***NOTE**-Setting the dial below the zero mark will reverse the flow of liquid through the pump.*

When setting the volume control, always approach the desired setting from a lower setting. This is because of a backlash or clearance between parts. For most accurate settings, change setting while unit is not rotating. Always tighten lock screws after setting.

CHECKING METERING PUMP OUTPUT

In some cases it may be required that the output of the metering pump be checked.

The procedure to follow in these instances is as follows:

Figure E-4. Not applicable.

MANUAL (KA-60)

***NOTE** - Customer to supply necessary piping and two test buckets.*

1. Move the test scale into position and mount one test bucket on the scale. Weigh and record the test bucket weight.
2. Put the sample pipe into the other bucket and run the mixer until asphalt starts to discharge. Stop the mixer and allow the pipe to drip one minute.
3. Place the sample pipe into the scale mounted test bucket and record the reading on the revolution counter.
4. Run the mixer until the asphalt level in the test bucket is near the top. Stop the mixer.
5. Allow the sample pipe to drip for one minute. Weigh the sample and subtract the weight of the sample bucket to obtain the weight of the asphalt.
6. Record the revolution counter reading and subtract the reading at the beginning of the test to obtain the number of revolutions used in the test.
7. Divide the weight of the asphalt by the number of revolutions to obtain the pounds per revolution. Adjust the metering pump if necessary and take another test to check results.

***NOTE** – Be sure to weigh the test bucket before each test as asphalt clinging to the sides of the test bucket will change its weight.*

PUGMILL CUBIC CONTENTS CHART

(Refer to Figure E-5.)

Mounted on the mixer is a chart giving the cubic feet content of the pugmill at various material depths. Also on the chart is the formula for determining the mixing time in seconds based on the material to be used, volume of material in the pugmill in cubic feet, weight of material in pugmill in pounds per cubic foot, and the output capacity of the mixer in tons per hour. The output capacity is based on the tons per hour the gradation unit is delivering plus the tons per hour the metering pump is delivering.

ACTUAL MIXING OPERATION

With the engine idling and the master clutch disengaged:

1. Carefully engage the aggregate clutch, then engage the master clutch (engine) until aggregate starts to discharge into the pugmill, then stop. This operation is performed to bring the aggregate flow up to the point of mixing.
2. Slow engine to disengage master clutch. Disengage the aggregate clutch.
3. Carefully engage the asphalt clutch, then engage the master clutch until asphalt issues from the spray nozzles.

You are now ready to mix. For normal operation, perform the following steps:

1. Carefully engage aggregate clutch.
2. Engage asphalt pumps clutch.
3. Engage pugmill clutch.

CUBIC CONTENTS CHART FOR MODEL KA-60 MIXER

MATERIAL LEVEL BELOW TOP OF PUGMILL, INCHES	PUGMILL VOLUME, CUBIC FEET
3	55.1
4	52.6
5	50.2
6	47.9
7	45.5
8	43.2
9	40.8
10	38.5
11	36.1
12	33.7
13	31.4
14	29.0
15	26.7
16	24.3
17	22.4
18	20.4

FORMULA

$$T = \frac{KVW}{C}$$

T = MIXING TIME, SECONDS.

$$K = \frac{60\ (\text{SEC.}) \times 60\ (\text{MIN.})}{2000\ (\text{LBS/TON})} = 1.8$$

V = VOLUME OF MATERIAL IN PUGMILL, CU. FT.

W = WEIGHT OF MIXING MATERIAL IN PUGMILL POUNDS PER CU. FT.

C = OUTPUT CAPACITY OF MIXER, TONS PER HOUR.

Figure E-5. Cubic Contents Chart.

4. Engage master clutch, (engine).
5. With material flowing through the pugmill, dam to obtain proper coating and correct level of material in the pugmill.

PUGMILL DAM

When the pugmill dam is raised to retard the mix, the material is delayed in the pugmill for a longer period of time resulting in a more thorough mixing action.

The position at which the dam should be maintained is determined by the quality of the discharging mix. If all the aggregate is not thoroughly coated, the dam should be raised just enough to produce thorough coating.

Do not operate the Mixer with the dam raised more than is necessary to produce thorough coating, as it will not improve the quality of the mix, but will cause an additional unnecessary load on the Mixer engine and drives.

PUGMILL DISCHARGE HOPPER

The hydraulic controlled pugmill discharge hopper permits surge storage and control of aggregate segregation.

The primary purpose of the pugmill discharge hopper is to prevent aggregate segregation.

The hopper should be allowed to fill up as much as possible without affecting the mix or overloading the pugmill drive and engine.

The depth of material in the pugmill and the height of the pugmill dam control the amount of the material that is normally allowed to build up in the hopper before dumping.

The operator, by observing the material as it discharges from the pugmill into the hopper, allows it to build up to a point just before it reaches the level of the mix in the pugmill, and before it retards the flow of material through the pugmill, then discharges it.

When changing trucks it may be necessary to allow the depth of material to build up slightly higher, for a brief period, not wanting to shut down the Mixer. However, it must be remembered that allowing the depth of material in the hopper to build up beyond the pugmill mixing level, retarding the flow, places additional load on pugmill drive and engine.

A continuous cycle of loading the hopper and discharging, can be established by the operator after he has become familiar with the operation of the hopper.

PUGMILL COVER

The pugmill cover serves as a housing to retain dust and all possible heat of the materials being mixed.

It also serves as a guard to prevent accidents.

***IMPORTANT**-Keep pugmill cover closed except when inspecting the mixing process.*

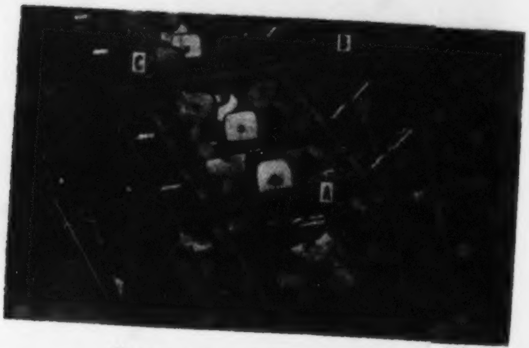


Figure E-6. Mixer Pugmill

THE MIXER PUGMILL *(Refer to Figure E-6.)*

The function of the pugmill is to thoroughly mix all materials into a thoroughly coated mixture.

On the two parallel paddle shafts (A) are mounted the paddle arms, half on each shaft.

The hubs of the paddle arms (B) are designed similar to an eight point socket wrench. This permits each paddle arm to be placed on the shaft at either 45° or 90° angle to the paddle arm adjacent to it for controlling the amount of mixing action in the pugmill.

Paddle tips (C) are fastened to each of the paddle arms at an angle so that as the paddles revolve the paddle tips force the material in the pugmill towards the discharge end.

The degree of mixing in the pugmill is entirely dependent upon the rate of flow of the material through the pugmill. The slower the material passes through the pugmill, the greater the amount of pressure exerted on each individual particle of aggregate. Similarly, as the rate of flow through the pugmill increases, the pressure on each individual particle of aggregate is reduced correspondingly.

The rate of flow of material through the pugmill is controlled either by the setting of the paddles, or by damming the flow of material discharging from the pugmill, or by the combination of both. The rate of flow should be set at a point where thorough mixing is obtained, but any further decrease in the rate of flow would not increase the quality of the mix, but would require more power and would result in reduced capacity.

The mixing pressure may be increased by damming the flow of material by raising the pugmill discharge dam gate adding more resistance to the movement of the mix through the pugmill.

Because the ease of mixing varies with different materials, the position of the pugmill paddles can be changed to retard or speed up the flow of material through the pugmill to obtain proper mixing.

The pugmill paddles normally are set at the factory to mix properly the low penetration asphalts with dense graded aggregates.

PUGMILL PADDLE SETTINGS

The following classifications of mixes, based upon their relative ease of mixing, will be helpful in selecting the proper pugmill paddle setting:

1. Easy mixes—all types of stabilization mixes including emulsion stabilization.
2. Average mixes—most bituminous mixes including cut-back asphalts, road oils, and tars when mixed with graded aggregates.
3. Hard mixes—low penetration asphalts with graded aggregates.
4. Extra hard mixes—those mixes where extraordinary conditions occur making coating of aggregates extremely difficult. The most common causes of such conditions are: attempting to coat the larger stone in an aggregate when there is an excess of fines to soak up the bitumens; attempting to mix cold aggregates with too heavy a bitumen; mixing aggregates that resist coating because of peculiarities in their chemical or physical structure; and attempting to coat particles of crushed stone that have a thick coating of fines adhering to each particle.

In order to obtain satisfactory coating of the above classifications, the pugmill paddles should be set to produce adequate "mixing pressures" for the existing classification of mix.

XA-60 PADDLE SETTINGS

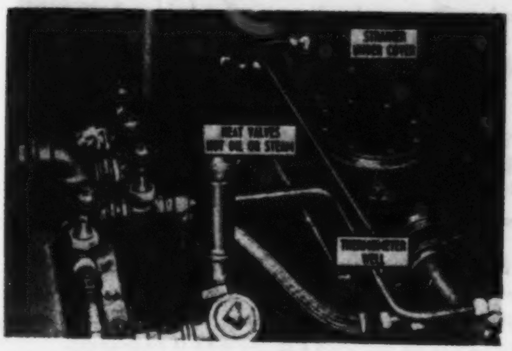
1. When mixing conditions fall in #1 classification of "easy mixes", all paddles except one on each shaft are set at 45° to the one adjacent to it. The last paddle on each shaft at the discharge end is normally set at 90° to the one next to it and is normally reversed to retard flow.
2. When mixing conditions fall in the #2 classification of "average mixes", starting at the charging end of the pugmill, 8 paddles on one shaft should be set at 45°, the remainder at 90°; and on the other shaft, 9 paddles should be set at 45°, and the remainder at 90°. The last paddle on each shaft at the discharge end is reversed.
3. For mixes falling in #3 classification, starting at the charging end of the pugmill, four paddles on one shaft should be set at 45°, the remainder at 90°; and on the other shaft, five paddles should be set at 45°, and the remainder at 90°. The last paddle on each shaft at the discharge end is reversed.
4. For mixes falling into #4 classification, the setting is the same as for #3 classification with the exception that the sixth and eleventh paddles on each shaft, counting from the discharge end, are reversed. This setting should not be used unless absolutely necessary, as extreme wear to the liner plates will result at the retarded paddles. In most cases, the mix specifications are not right if it is necessary to resort to retard paddles to obtain proper coating. If #3 setting will not produce proper coating, an attempt should be made to determine what is causing the difficulty and the cause rectified, if possible.

TO REVERSE THE PADDLES:

Paddles are reversed by transferring a paddle from one shaft to the other.

1. Remove the two bolts holding the paddle to the pugmill shaft.
2. Remove the paddle and reinstall on the opposite shaft.
3. Install bolts and tighten.

As the flow of material is retarded, the mixing horsepower is correspondingly increased. If the pugmill is already working to the limit of its power, then further retarding necessitates reducing the volume of material entering the pugmill, or in other words, reducing the mixing capacity. Also the mixing capacity must be reduced if further retarding dams up the material so it overflows the pugmill.



453-485

Figure E-7. Asphalt Sump

ASPHALT SUMP AND STRAINER *(Refer to Figure E-7.)*

The sump consists essentially of a steam jacketed cylinder inside of which a cylindrical brass strainer is mounted.

In normal operation, the screen should be removed and cleaned after every forty hours of operation; however, on some types of asphalt containing an excess amount of foreign materials, the screen should be checked and cleaned more often.

TO CLEAN THE STRAINER:

1. Turn off supply pump and mixer.
2. Remove cover at top of sump and lift strainer out.

CAUTION: *If the asphalt in the sump is hot, the operator should use caution in removing the strainer so he will not be burned by the asphalt.*

When mixing "fast breaking" emulsions, if there is any indication of the emulsion breaking, it may be necessary to remove the strainer from the sump. The resistance to the flow of the bitumen through the strainer may cause the emulsion to break.

THERMOMETER *(Refer to Figure E-7.)*

Located inside the asphalt sump is a thermometer inside a tube. To read the temperature of the asphalt, remove the pipe plug from the top of the sump and pull out the thermometer.

SPRAY BAR AND NOZZLES

As the aggregate discharges from the hot elevator into the pugmill it is sprayed with a film of bitumen from the spray bar. The spray nozzles are inserted into the spray bar, which is located in the spray chamber. The nozzles have slotted holes which form the discharging asphalt into a fan shaped spray giving a portion of the aggregate a preliminary coating before being mixed in the pugmill.

In normal operation the spray nozzles require little attention. Check the nozzles to make sure the fan shaped spray of asphalt is approximately transverse to the aggregate flow.

Periodically check the nozzles for plugging. Any foreign material can easily be dislodged by inserting a piece of stiff wire into the nozzle slot or the nozzles can be removed and cleaned if necessary.

NOTE: *When mixing "fast breaking" emulsions, the spray nozzles should be removed from the spray bar, so the resistance to flow will be cut to a minimum.*

CLEANING THE PUGMILL

The pugmill should be cleaned out thoroughly each time the plant is shut down. This is especially important when mixing the heavier asphalts as any mixed material left in the pugmill may harden to such an extent that damage to the pugmill drive may result when the plant is again started.

TO CLEAN THE PUGMILL:

1. Disengage the aggregate clutch and asphalt clutch. This will stop the flow of aggregate and asphalt to the pugmill.
2. Allow the pugmill to run and lower the dam gate to its lowest point. Continue to run the pugmill until all material possible has been discharged by the paddles.
3. Now engage the aggregate clutch carefully and run dry aggregate through the pugmill until all coated material is removed.

HOT OIL OR STEAM HEATING

The Mixer is equipped with a full flow heating system adaptable to either steam or hot oil type of heating.

The heating system consists of steam or hot oil jackets at various points and inter-connecting piping.

The following parts of the Mixer are steam or oil jacketed:

1. Asphalt Supply Pump.
2. Asphalt Metering Pump.
3. Asphalt Strainer
4. Spray Bar.
5. Pugmill.
6. All Asphalt Lines except at fittings in the line or where a pipe nipple is too short to make jacketing practical.

The piping connecting the jackets falls into two classifications; supply lines and return lines. Each heating jacket has two ports; an inlet port and an outlet port. Supply lines connect to the inlet ports and return lines connect to the outlet ports.

The hook-up of main supply and return lines and the operation of steam heating system is slightly different than when oil is used for heating.

STEAM HEATING

The flow of steam through the system starts at the main steam line inlet. Lines branch out to the various steam jackets, connecting to the inlet ports on the jackets.

From the jackets, the steam (or condensate) flows to the return line.

HOT OIL HEATING

When hot oil is used in the heating system, the flow of oil enters the system at the lower line.

The return line for hot oil is connected at the top line, just the reverse of when steam is used.

In operation, the flow of oil through the system must be balanced by adjusting the valves to each component or jackets of the heating system. For example:

If the metering pump is not heating to proper temperature, the valves to the other units will have to be closed slightly to provide more heat to the pump jacket.

The operator, by observing the various units in the system, can soon learn to balance the flow of oil through the system to provide satisfactory operating temperatures.

DATA ON PIPING, TANKS & COILS

1. DIRECTION OF STEAM OR OIL FLOW.

Basically the same over-all piping can be used with steam or hot oil heating system. The main differences is the direction of the flow of steam or oil through the system.

The direction of flow of steam should always be downward. The steam should always be introduced at the highest point, of the various systems to be heated, to allow condensate to drain out.

When using hot oil heat, the direction of flow is just the reverse of steam. Hot oil should always be introduced at the lowest point and the direction of flow upwards. To bleed a line, crack it open at its highest point.

2. TANK INSULATION.

It is advisable to insulate asphalt storage tanks with at least two, and preferably three inches of mineral wool, magnesia, or equal.

3. HEATING COILS

Tank heating coils must be one and one half or two inch nominal diameter black pipe. They should preferably be welded. The length of coils will depend upon the desired heating rate.

Tanks	Minimum Length	Preferred Length
Uninsulated	1 ft. per 20 gal.	1 ft. per 16 gal.
Insulated or Buried	1 ft. per 30 gal.	1 ft. per 25 gal.

4. PIPING MATERIALS AND DIAMETERS

Use standard weight black pipe. Copper and copper alloys should be avoided.

Jumpers made of black pipe should be one inch diameter. Use the same diameter with flexible steel hose.

Connections of tank coils with Hot Oil Manifolds should be two inch diameter if black pipe is used. Use same diameter with flexible steel hose.

Flexible Steel Hose is definitely recommended whenever it will save labor and/or allow for expansion.

5. AUTOMATIC TEMPERATURE CONTROLLERS
(Hot Oil Systems)

Temperature-controlled solenoid valves are recommended. They are normally installed on the tank coil outlet and they should be at least 3/4 inch and preferably 1 inch size.

GENERAL LUBRICATION INFORMATION

This section contains lubrication instructions which are supplemental to, and not specifically covered in, the lubrication order. For the current Lubrication Order, refer to LO 5-3895-287-12.

DETAILED LUBRICATION INFORMATION

a. Care of Lubricants and Lubricating Equipment. Keep all lubricants in closed containers and store in a clean, dry area away from heat. Do not allow dirt, dust, water, or any other foreign materials to come into contact with lubricants. Keep all lubrication equipment clean and ready for use.

b. Cleaning. Use an approved cleaning solvent to wipe all surfaces clean around point of application before applying lubricant.

CARE AND ADJUSTMENTS OF V-BELT DRIVES

ALIGNMENT

Improper alignment is one of the most common causes of excessive belt and sheave wear. To check alignment, place a straight edge across the face of the sheaves. If sheaves are in line, the straight edge will squarely contact the face of both driving and driven sheaves.

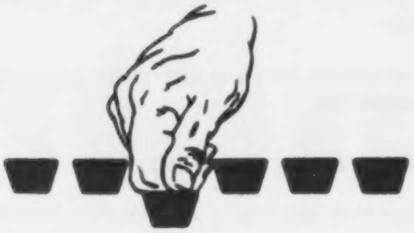
REPLACEMENTS

When new V-Belts are necessary, install a complete set. If some new belts are put on a drive with worn or stretched belts, the new belts, being shorter, will carry more of the load.

When new belts are installed, make sufficient slack in the drive so that the new belts can be placed easily in the proper grooves. Always order replacement belts by part number.

INSTALLATION

The driven unit should be moved toward the drive unit so that the belts may be placed in the sheave grooves by hand. Under no circumstances should belts be forced into the sheaves with crowbars, wedges, screwdrivers or bars of any kind.



A simple test which can be made to check V-belt drive tension is illustrated above. Press down firmly on each individual belt. When the top can be depressed so that it is in line with the bottom of the other belts on the drive, the correct amount of tension has been applied. Each belt should be given this test individually.

Another good method of checking proper tension of V-belts is by "striking" the belt with your fist. Slack V-Belts feel dead under this test, while properly adjusted V-belts vibrate and feel alive.

TENSION

It is not necessary to pull V-Belts exceedingly taut. Tighten only enough to take out slack and undue sag. When belts are too tight, bearings are apt to burn out or wear faster, even if well lubricated. Excessive tension stretches and weakens belts.

On the other hand, if belts are too loose they slip and slide easily under load increases, resulting in excessive wear to both belt and sheave.

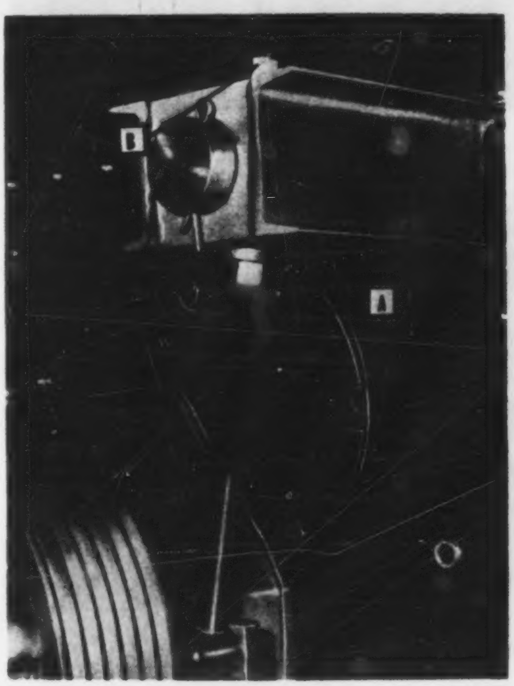


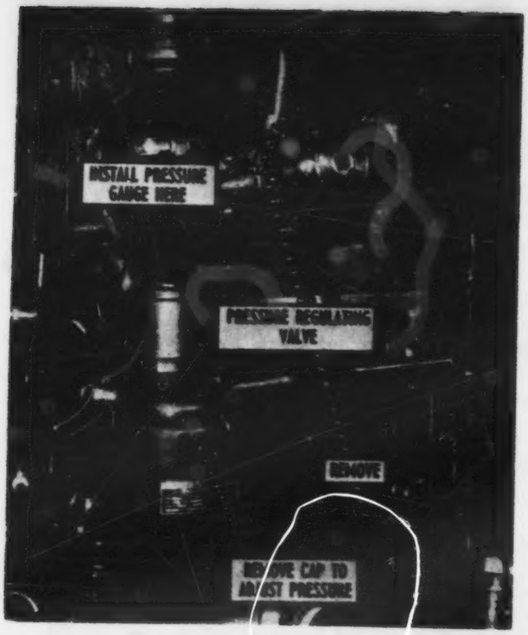
Figure G-1. Main Drive V-Belts

MAIN DRIVE V-BELTS *(Refer to Figure G-1.)*

The main drive V-Belts are adjusted by a turnbuckle on the pugmill gear box.

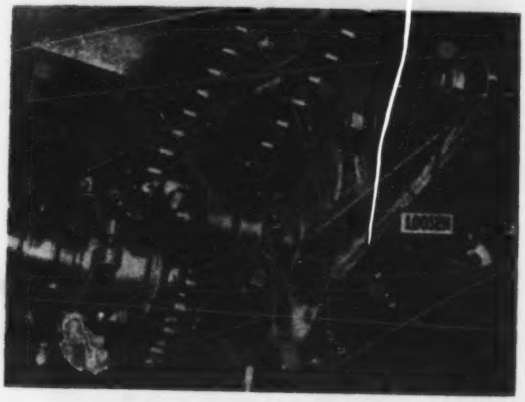
TO ADJUST:

1. Loosen nut A.
2. Take up belt slack by tightening nut B.
3. Tighten nut A.


INSTALL PRESSURE GAUGE HERE
PRESSURE REGULATING VALVE
REMOVE
REMOVE CAP TO ADJUST PRESSURE

463-563

Figure G-2. Metering Pump Drive Chain



463-558

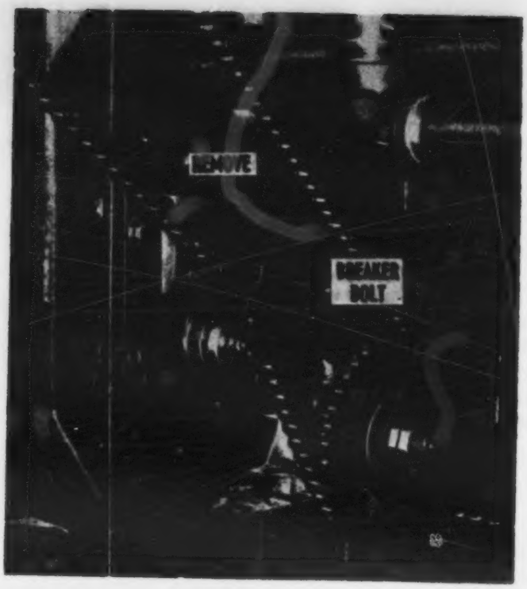
Figure G-3. Pumps Countershaft Drive Chains

DRIVE CHAINS *(Refer to Figures G-2 through G-4.)*

All drive chains except the revolution counter drive chains are adjusted by moving their respective idlers.

TO ADJUST:

1. Loosen or remove two bolts on idler mounting bracket.
2. Set idler for correct chain tension.
3. Tighten bolts.


REMOVE
BREAKER BOLT

463-557

Figure G-4. Supply Pump Drive Chain

When all normal take-up has been used, remove a half link or full link from the chain and adjust as described above.

PUMP DRIVE BREAKER BOLTS *(Refer to Figure G-4.)*

The pump drives are protected by a breaker bolt located in the hub of the drive sprocket.

Should either breaker bolt break while the pumps are in operation, the Mixer should be stopped immediately.

Find and remove the cause of breakage and install a new breaker bolt.

TO REPLACE BREAKER BOLT:

1. Align shaft hub bracket with sprocket bracket.
2. Install new bolt and spacer.

Periodically check breaker bolt for worn bolt shank and replace if badly worn, before it breaks.

Figure G-5. Not applicable.

Figure G-6. Not applicable.

METERING PUMP *(Refer to Figure G-7.)*

The simple moving parts of the metering pump will give dependable service, if clean liquids are used to eliminate excessive wear on the close fitting parts. All fittings on suction side of pump should be tight, so that full suction can be maintained at all times.

Do not run the pump empty any longer than necessary. This pump depends upon the liquid pumped for internal lubrication. Lack of lubrication will cause damage to the working parts.

Periodically inspect the packing glands for leaks. When take-up on the packing glands is used up, new packing should be installed.

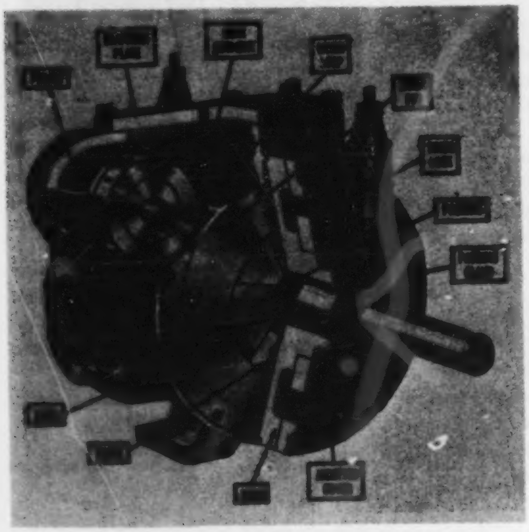


Figure G-7. Asphalt Metering Pump

TO INSTALL NEW PACKING:

It is always wise when replacing the packing to check the shaft in the area of the stuffing box for scoring. Replacement with another set of packing will be ineffective in controlling the leakage if the previous packing has critically damaged the shaft; in which case, the rotor and shaft assembly must be replaced.

1. Remove packing gland and slide back on shaft.
2. Remove all old packing and clean stuffing box.
3. The bottom adaptor ring should be installed first; lips of "V" rings should face inward toward liquid pressure.

   ***NOTE** - Be sure to install each ring so the joints are staggered, that is, not lapping over or near the joint of preceding ring.*

   Packings are furnished in sets with correct number of rings.

4. After the last ring has been installed, insert gland into the stuffing box. Tap packing lightly into place using brass or lead hammer against the gland. Then, withdraw gland and re-insert using only hand pressure. If gland must be forced in, the shaft is misaligned.
5. Tighten gland nuts, being careful not to use force. Then follow the procedure for packing adjustment as given below.

TO ADJUST PACKING:

1. Tighten the packing gland a very small amount at a time and check the gland temperature for several minutes after each adjustment for signs of overheating. **Never exert strong pressure on the gland nuts.** V-type packing is especially sensitive to gland pressure and can severely damage the shaft under excessive pressure.
2. If moderate tightening of gland no longer holds leakage to a satisfactory minimum without overheating, the old packing should be replaced with a complete new set. **Never add a new ring to old packing.**

PRESSURE CONTROL VALVE (Refer to Figure G-2.)

A pressure control valve is attached below the pump. Install a pressure gauge where shown in Figure G-2 and periodically check the pressure when spraying. The pressure should never drop below 12 P.S.I.

TO ADJUST PRESSURE:

1. Set spray - circulate valve to circulate asphalt. Install pressure gauge.
2. Set metering pump dial to 100 setting.
3. Remove cap and turn adjusting screw until pressure gauge shows a reading of 15 P.S.I.

DISASSEMBLY

CAUTION – *When disassembling the pump to replace liner, gear segment, or pinion, use the following procedure to insure accuracy of reassembled pump.*

1. Remove blanking plate.
2. Match-mark pinion and gear segment.
3. Make a note of the dial setting.

If a new pinion and gear segment are to be installed, be sure to mark the new parts at the same point that the old parts are marked.

Failure to follow this procedure will cause output of reassembled pump to be different from that shown on the metering pump capacity chart.

A. HEADS, BEARINGS, & PACKING

If the heads and the casing do not have matching notches, it is advisable to place a matching mark on each head and the casing **BEFORE DISASSEMBLY** to assure that they will be re-assembled in exactly the same position. To take off either head assembly, remove the head capscrews, the two stud nuts on the horizontal centerline of the head, and tap the head loose with a lead hammer, or pry it loose with a screw driver. After drawing head assembly from the shaft, and removing the gland nuts, it should be possible to easily remove the gland and packing by hand. If necessary, the cover to the jacketed type head can be taken off by removing the capscrews around the stuffing box.

B. VANES AND ROTOR-AND-SHAFT ASSEMBLY

Removal of outboard head assembly (on side opposite the shaft coupling side) allows convenient access for withdrawing vanes. If only vanes are to be replaced, remove old vane from top slot; replace with new vane; turn rotor so next vane is in top position; replace it, and proceed to replace the others in the same manner. If the vanes are swollen or jammed in their slots, withdraw the rotor-and-shaft from pump and drive them out with a suitable blunt instrument. Removal of the push rods also requires taking the rotor-and-shaft out of the pump.

C. LINER AND GEAR SEGMENT

Before the liner can be pulled from the pump casing, it is necessary to remove one of the head assemblies and the gear segment. Access to the gear segment can be obtained by removing the blanking plate. Loosen the setscrew that holds the gear segment to upper liner pin. The two liner pins will then slip endwise out of the liner and the gear segment can be removed through the opening in top of pump. Loosened segment may have to be freed from mesh with pinion by rotating control dial. The liner will now slip out easily.

D. PINION

The pinion is a slip fit on the dial control shaft and (after removal of liner and gear segment) can be easily released by 1) loosening dial setscrew and removing dial, 2) removing retainer screws and sliding retainer off shaft, and 3) pulling control shaft out of Vari-Flo casing.

REASSEMBLY

A. PINION

Place key into position on the control shaft and insert shaft into the control housing of pump casing, holding the pinion by hand inside. After starting shaft into pinion, rotate shaft until key engages keyway in pinion, then push the shaft home into back retainer as far as it will go. Attach front retainer and dial.

B. LINER AND GEAR SEGMENT

Liner and gear segment are easier to replace and locate in position properly if inboard head (less packing and gland) is replaced first. The packing and gland for this head should be replaced later, after liner, rotor-and-shaft and other heads are in position. Insert liner so pin holes are alongside the control dial, taking care that the wide rib is at the top and narrow rib is at the bottom. Then lower the gear segment through opening in top of cylinder so that setscrew of segment will lock against the upper liner pin. The control dial may have to be rotated to permit segment to mesh with pinion and drop into place. Insert liner pins through liner flange holes and through holes in segment. With liner pins flush to outer faces of liner, adjust the position of the gear segment along pins for proper meshing alignment with pinion, and tighten setscrew.

Be sure, after completing assembly of Vari-Flo to reset the liner stop of the gear segment in accordance with instructions given under "Setting the Liner Stop."

C. VANES AND ROTOR-AND-SHAFT ASSEMBLY

If the rotor-and-shaft has been withdrawn from the pump, place the bottom three vanes in slots, cupping rotor in hand, and insert all the push rods. Be sure that the wearing edge of the vanes (rounded or beveled edge) is outward to contact the bore of the liner. Slide the rotor-and-shaft assembly into liner chamber, taking care that the shaft does not strike and damage face of opposite head when locating it in bearing hole. Insert remaining three vanes.

D. HEADS, BEARINGS AND PACKING

Before replacing either head, clean off the old sealing compound from the side that faces the cylinder and inspect this face carefully for burrs, dirt, or surface imperfections which might prohibit a tight seal. Apply a thin coat of new sealant, being careful to avoid excessive use of sealant (which may flow between liner and pump casing, causing difficulty in turning the liner with control dial). Wash out stuffing box of head and smooth out all burrs or rough spots on shaft with emery to prevent damage to packing.

Replace the head (less packing and gland) on the studs of pump casing, making sure it is replaced in exactly the same position as it was previously assembled, with the pressure groove on the head's inner face leading away from the port below volume control dial. When these pressure grooves are in the correct position, the head with the liner lock screw will be on volume control dial side of pump and the lock screw will be above the bearing chamber. The head which does not have the liner lock screw has instead a blank boss (normally drilled for the liner lock screw) which will be on side opposite volume control dial and the boss will be located below the bearing chamber.

***NOTE** - These heads are cast with a notch on the edge of the head which should match an* *identical notch in the pump casing. These external reference points for head location on casing are stressed carefully for two very important reasons: 1) Since the bearing hole center is offset from the head center, it can be moved out of proper alignment with shaft by rotating head in either direction before placing on casing, and 2) the pressure grooves must lead horizontally toward port of high pressure side for the Vari-Flo to function properly. If the cover for the head has been removed, replace it and the gasket so that the inlet and drain holes are approximately on a vertical centerline with respect to each other. After the head has been positioned properly, replace the nuts on both cylinder studs and draw tight; replace all capscrews and tighten firmly. After both heads are in place, the packing and glands may be replaced according to the procedure outlined in the section on packing replacement and adjustment.*

NOTE: If new bearings are replaced, they should be carefully "run in".

TROUBLES AND THEIR CURES

LEAKAGE

If leakage appears from between the casing and the head, the head should be removed, sealing compound cleaned off, and the inner face inspected for burrs, dirt, or other surface imperfections. Reassemble using fresh coat of sealing compound on the faces. It is advisable to allow compound to dry for two hours before operating the unit if possible.

If there is any leakage of steam or liquid between the cover and the head even after tightening the capscrew firmly, the cover should be removed and its gasket replaced. Leakage around the shaft should be controlled by proper adjustment of the packing glands; if leakage is excessive even with proper adjustment or the glands overheat when the leakage is controlled, packing should be removed and completely replaced.

OVERHEATING OF BEARINGS

Abnormally hot bearings may result from:

1) the packing being worn out or adjusted too tightly

2) misalignment of the unit; remove the inboard bearing from the stuffing box...if the alignment is proper, it should re-enter the stuffing box without force.

3) pumping a hot liquid; bearing temperatures will usually run somewhat hotter than the liquid being pumped. When handling a high temperature liquid, care should be taken that a lubricant is used which will not melt and run out of the bearing.

4) insufficient lubrication; bearings with standard grease cups should be serviced regularly and lubricant levels in the automatic-type of lubricators should be inspected and kept adequately full. New bearings may be damaged permanently by poor attention to their conditioning.

NOISE

When a pump has been completely drained and is full of air, some noise may occur when the pump is restarted and the air is purged out of the system. The noise, although seldom present, is usually of short duration and causes no damage. With proper pumping conditions, the pump will be quietest with the dial set at 100. As the dial setting is decreased, it is normal for the noise to increase somewhat. If the pump is still abnormally noisy, the vanes should be examined for possible damage.

SUPPLY PUMP (Refer to Figure G-8.)

Periodic inspection should be made of the packing gland (A) to see that the packing is adjusted properly. When take-up on the packing gland is used up, new packing should be installed.

TO INSTALL NEW PACKING

1. Remove the two nuts (B), one on each bolt of the packing gland plate (C).
2. Slide packing gland plate (C) and bushing back on pump shaft.
3. Remove old packing.
4. Coat new packing with grease and install on shaft.

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Figure G-8. Supply Pump

5. ***IMPORTANT*** *- Normally there are 3 packing rings in a set and these should be installed so the joints are staggered around the shaft to assure a perfect seal.*

6. Slide bushing and packing gland plate back into position, replace nuts, and draw up snug, but not tight.

TO ADJUST PACKING:

1. The packing gland nuts should be tightened only as much as needed to stop seepage. Even a small amount of seepage is not objectionable. It is much better than to have packing too tight causing heating and damage to pump shaft.

2. Test adjustment by turning pump by hand to be sure packing is not too tight and binding shaft.

Before putting pump in operation, remove front and with feeler gauge check clearance of .018" to .020" all around between rotor and casing. This is only assurance that shaft is properly aligned.

PUMP HEAD GASKETS

If it is necessary to dismantle the pump, in putting it back together again, do not use thicker gaskets than those originally furnished with the pump. The use of thicker gaskets will allow end play and slippage, decreasing the capacity and efficiency of the pump. In replacing gaskets, be sure they are not broken or leakage may occur. Always be sure pump does not bind because of lack of gaskets.

DISASSEMBLY

Remove hex nuts and take off head, which has idler pin held in place by a nut. Idler with bushing slides on pin with disc at end of pin. Pipe flanges are held to casing by studs and hex nuts.

Rotor and shaft may be pulled out of the case. Note thrust washers and back of rotor hub.

Packing gland is held in place by studs. Rotor bearing sleeve is mounted on the case with studs and nuts.

UNSATISFACTORY PUMP OPERATION

Should the transfer pump fail to operate satisfactorily, check for the following possible causes:

1. **Air Leak in Suction Line** - make sure all fittings in suction line are tight and not pulling air into the line.

2. **Cold Spot in Line** - too great a length of suction line unjacketed, allowing the bitumen to "freeze" in the line at that point. A cold spot can be detected by feeling the temperature of the pipe at various stations beginning at the storage tank and working toward the pump. If the line is warm or hot, the bitumen is flowing at that point. If the line is cold at any point there is a possibility that the bitumen at that point is sufficiently stiff to prevent proper flow. Heat cold sections by discharging live steam around the "cold spot" or by heating with some type of torch.

3. **Pump Needs Priming** - to prime pump, screw the male end of a one-half inch street elbow into the bitumen drain cock, and screw a piece of one-half inch pipe approximately one foot long into the female end of the street elbow. Turn the pipe so it extends downward. With pump running, take a pail full of bitumen and bring it into a position so the pipe is immersed in the bitumen. Then open cock. The suction created will pull bitumen out of the pail and cause a sufficient prime. Close cock before bitumen in the pail lowers sufficiently to allow air to be pulled into the priming pipe.

MAIN GEAR BOX

The pugmill gear box requires no maintenance other than periodic and proper lubrication.

If the pugmill shafts are removed from the gears, the position of the shafts, relative to each other, and position of the gears, should be marked so that they can be reassembled as before, to maintain proper timing of the paddle shafts.

PUGMILL PADDLE TIPS

The paddle tips are subjected to high abrasive wear and should be checked weekly to determine the extent of wear.

Should the outer edge of the paddle tip show considerable wear, while the face of the tip has worn only slightly, the tip can be adjusted to maintain proper clearance. Should the tips be worn beyond the adjustment, they can be turned end for end, for maximum life.

PUGMILL LINER PLATES (Refer to Figure G-9.)

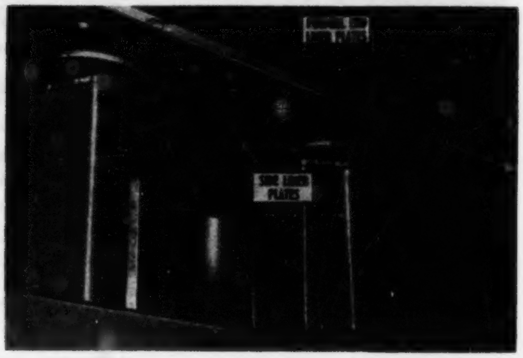
The bottom, sides, and charging end of the pugmill are protected from wear by replaceable abrasion resisting liner plates.

There are 21 liner plates on each side and 5 on the charging end of the KA & KB-60 Mixers. On the KA & KB-70 Mixers there are 24 in each side and 5 at the charging end. Each of the side liner plates is interchangeable with any other liner of the same shape.

Check the liner plates at the end of each day to determine the extent of wear. Some types of aggregate can cause more extensive wear than others.

The liners at the discharge end will wear faster because more mixing pressure is built up there than at the charging end.

Moderately worn discharge end liners should be interchanged with charging end liners. When any liner wears through, it must be replaced immediately to prevent damage to the pugmill. Keep new liner plates on hand, available when needed.



463-443

Figure G-9. Pugmill Liner Plates

TO REPLACE SIDE LINER PLATES

1. Remove pugmill cover and scrape accumulated material from pugmill liner plates.
2. Remove bolts from liner to be replaced.
3. Pry liner plate away from pugmill shell and remove it through top of pugmill.
4. Place new liner plate in position and bolt in place.

TO REPLACE CHARGING END LINER PLATES

1. Remove the spray chamber housing.
2. Remove the four bolts from the plate to be replaced.

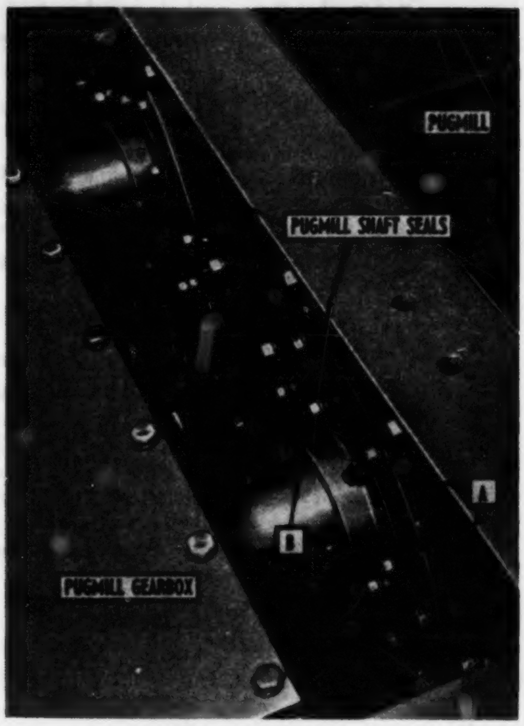
   ***NOTE** - If one of the two lower plates is to be replaced, it will be necessary to remove the upper corresponding plate.*

3. Pry up the upper plate and rotate the lower plate to remove it.
4. Insert replacement plate and bolt in position.

When installing new liner plates, be sure they fit the curvature of the frame. It may be necessary to shim with washers between liner plates and frame.

PUGMILL SHAFT SEALS *(Refer to Figure G-10.)*

Seals are located on the pugmill drive shafts between the charging end of the pugmill and the pugmill gear box. These seals prevent seepage of material through the end of the pugmill. Since these seals are wearing items it will eventually become necessary to replace them.



463-444

Figure G-10. Pugmill Shaft Seals

TO REPLACE SEALS *(Refer to Figures G-10 & G-11.)*

1. Remove nuts (A) holding large seals in place and remove large seals.
2. Remove nuts (B) holding small seals in place and remove small seals.
3. Remove shims, spacer, and inner small seal.
4. Replace with new seals and reverse above procedure for installation.

***NOTE**: It may be necessary to add shims to keep the large seals from rubbing against the small seals.*

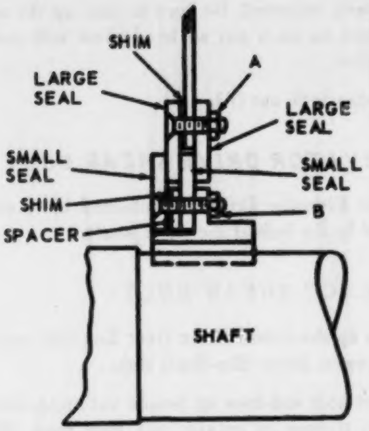


Figure G-11. Pugmill Shaft Seals

TIRES AND WHEELS

When towing the Mixer, check tires and keep inflated to proper pressure, 75 lbs. Keep wheel retainer lug nuts tight. Do not exceed maximum recommended towing speed of 20 M.P.H.

If the Mixer is to be set up on a job over a period of 3 to 4 months, it is advisable to remove the tire and wheel assemblies and store them indoors.

BRAKE SYSTEM

Air to operate the brake system is supplied by the prime mover used to tow the Mixer.

The air pressure actuates an air-to-hydraulic conversion cylinder, which supplies oil to actuate the hydraulic brakes.

PREVENTATIVE MAINTENANCE

A schedule for the periodic adjustment, cleaning, inspection, and lubrication of brake equipment should be established by the operator on the basis of past experience and severity of operation.

To compensate for this wear, brakes should be adjusted as frequently as required to maintain satisfactory operation and maximum safety.

Brakes should be cleaned, inspected, lubricated and adjusted each time the hubs are removed.

ADJUSTMENT *(Refer to Figure G-12.)*

Following overhaul or when new linings are installed, the initial adjustment should be carefully made to both properly locate the curvature of the lining to the drum and to obtain the proper clearance. Adjust shoes at final assembly of brake to .008 clearance between lining and drum at anchor end, and .020 at adjusting end.

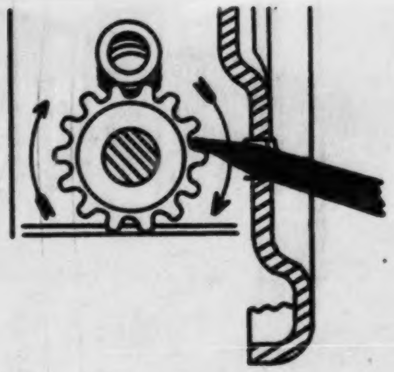


Figure G-12. Brake Adjustment

Subsequent adjustments to compensate for lining wear are made with the adjustment wheel.

1. Snap out cover cap.
2. Insert screwdriver in slot and turn in a downward direction, as shown in Figure G-12.)
3. Turn adjustment wheel until brake lining contacts drum.
4. Ease off on adjustment wheel until the wheel turns freely.
5. Replace cover cap.

MASTER (ENGINE) CLUTCH ADJUSTMENT

On the Mixer, the master clutch requires no adjustment. If clutch begins to slip at full load, remove 3 set screws on cover plate, pull out old shoes and replace them.

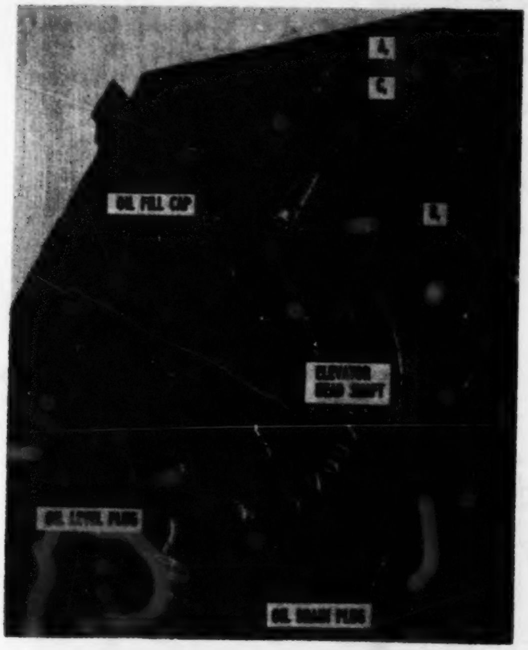
882 HOT ELEVATOR

BUCKET LINE ADJUSTMENT *(Refer to Figure G-13.)*

Check the slack in the bucket line through the inspection doors.

Observe the action of the bucket line while in operation. When bucket line slack reaches a point where the buckets are apt to strike the elevator housing, it should be adjusted.

Do not tighten bucket line too tight. Allow as much slack as possible to prevent excess strain on headshaft bearings, sprockets, and bucket chain.



458-185

Figure G-13. Hot Elevator Bucket Line Adjustment

TO ADJUST BUCKET LINE:

1. Loosen lock nut (A) on take-up bolt (B). There is a take-up bolt on each side of the elevator.
2. Take up nut (C) until bucket line tension is properly adjusted. Be sure to take up the same amount on each nut so head shaft will remain parallel.
3. Tighten lock nut (A).

HOT ELEVATOR DRIVE SHEAR BOLT

The Hot Elevator Drive is protected by a shear bolt located in the hub of the drive shaft.

TO REPLACE SHEAR BOLT:

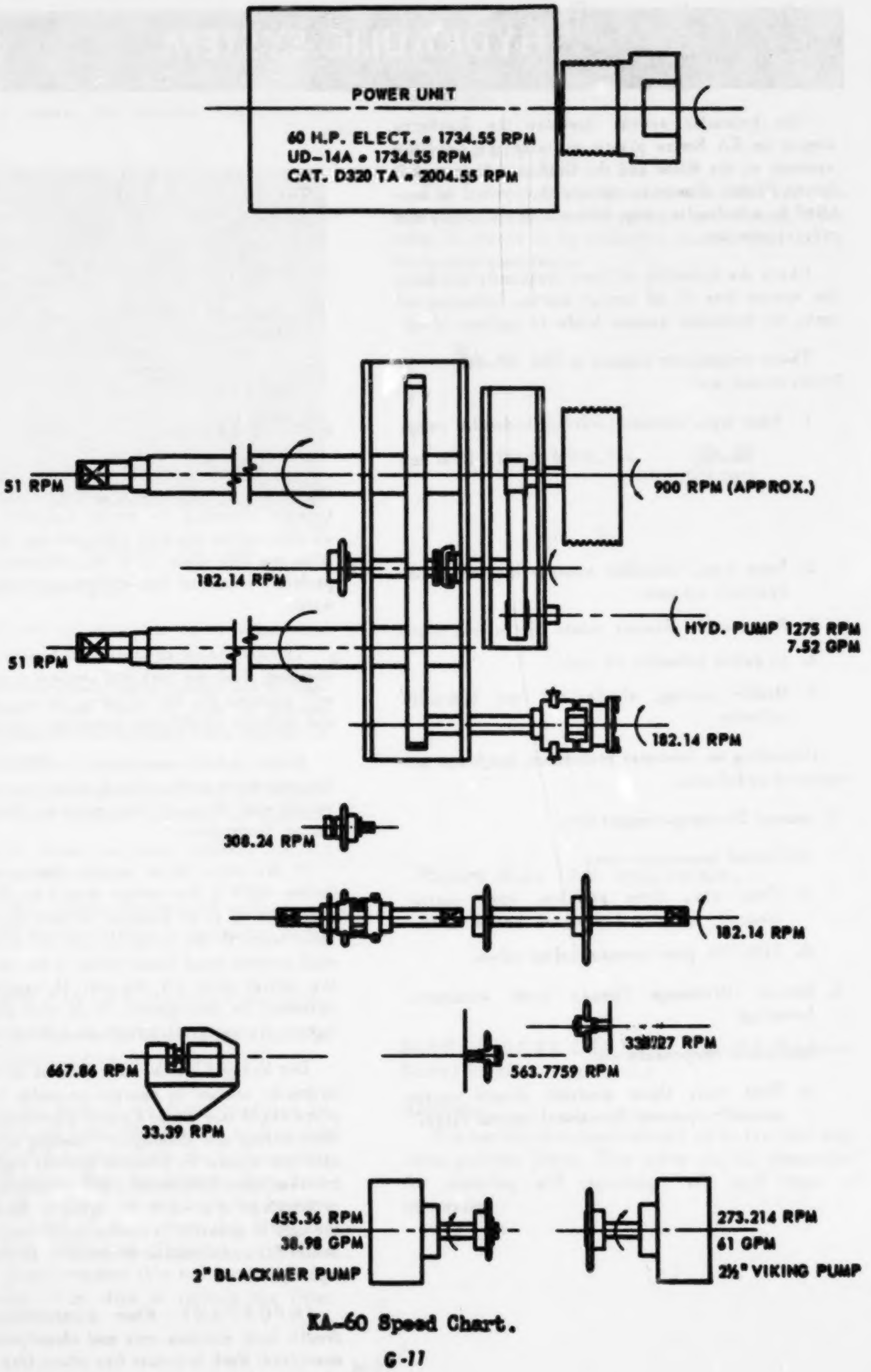
1. Line up the holes of the Gear Box Hub and the Universal Drive Slip-Shaft Hub.
2. Insert bolt and draw up inside nut snug, but not tight; tighten up outside nut, then back off inside nut to lock the two.

Periodically check shear bolt for worn bolt shank and replace if badly worn before it breaks.

DISCHARGE CHUTE LINER PLATE

The elevator discharge chute has one replaceable liner plate that should be inspected periodically for wear.

Some types of aggregate will have a more rapid wear rate on this liner than other aggregates. A periodic inspection should be made to establish a rate of wear and interval when a new liner should be installed. It should be replaced when worn thin, before the outer housing is exposed to wear. New liner plates should be kept on hand, available when needed.


POWER UNIT
60 H.P. ELECT. = 1734.55 RPM
UD-14A = 1734.55 RPM
CAT. D320 TA = 2004.55 RPM
51 RPM
900 RPM (APPROX.)
182.14 RPM
HYD. PUMP 1275 RPM
7.52 GPM
51 RPM
182.14 RPM
308.24 RPM
182.14 RPM
338.27 RPM
667.86 RPM
563.7759 RPM
33.39 RPM
455.36 RPM
38.98 GPM
2" BLACKMER PUMP
273.214 RPM
61 GPM
2½" VIKING PUMP

KA-60 Speed Chart.

HYDRAULIC SYSTEM

Section H

The hydraulic system operates the discharge hopper on KA Series plants and also the sampling systems on the Mixer and the Gradation Unit on KB Series Plants. Power to operate the system is supplied by a hydraulic pump driven from the torque arm reducer gear box.

Check the hydraulic oil level frequently and keep the system free of all foreign matter. Including oil tank, the hydraulic system holds 15 gallons of oil.

Those components common to the KA-60 Series mixers are:

1. Vane type, constant delivery hydraulic pump.

   KA-60 – 7.3GPM @ 1275 RPM and 1100 PSI.

2. Sump type, cleanable strainer located inside hydraulic oil tank.
3. Replaceable element, return line micron filter.
4. 15 gallon hydraulic oil tank.
5. Double acting, single rod end hydraulic cylinder.

Depending on customer preference, machines are equipped as follows:

I. **Manual Discharge Hopper Only**

   Additional components are:

   A. Four way, three position, open center, manually operated directional control valve.

   B. 1100 PSI, pilot operated relief valve.

II. **Manual Discharge Hopper (with Automatic Sampling)**

   Additional components are:

   A. Four way, three position closed center manually operated directional control valve.

MAINTENANCE

The hydraulic system is a most important part of the mixer. It will operate smoothly with little maintenance providing the proper hydraulic oil is used, all connections are kept tight, and the oil strainer and filter are kept clean. It is most important to keep oil perfectly clean and free of dust and sludge as well as water.

The oil should be inspected frequently and when changed, flush the tank and strainer thoroughly. This will increase the life of pump, valves, and cylinders and maintain an efficient operating system.

Under certain atmospheric conditions, condensation may occur in the oil tank which can collect in the valves and filter. If this occurs, drain and clean system thoroughly.

If the mixer is to operate during cold weather (below +32°F.), the system should be allowed to circulate for 15 to 30 minutes, or until the oil manifold feels warm to the touch. It may be desirable to install electric head heater bolts in the oil tank to take the initial chill off the oil. If continuous winter operation is anticipated, it is advisable to use a lighter viscosity oil. *(Refer to Lubrication Section.)*

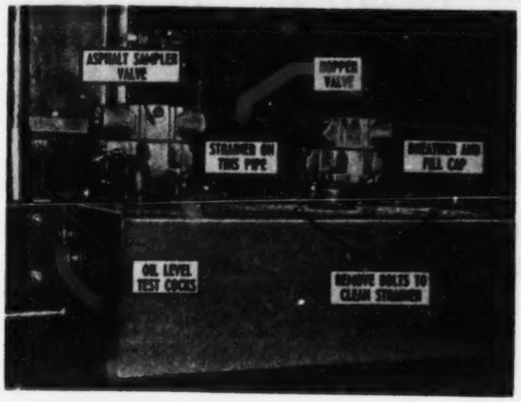
Dirt and grit are the main causes of failure of the hydraulic system to operate properly. A very small piece of grit may cause a valve to become inoperative. Dismantling and thoroughly cleaning a unit may enable the system to function without replacement. If, however, upon disassembly and inspection any spools or housings of a valve are found to be scored, or if the unit in question is proven defective, contact your dealer for authorization to return it to the factory for replacement.

***IMPORTANT:** When disassembling any hydraulic unit, extreme care and cleanliness should be exercised. Work in a dust free place. Use clean tools, cloths, and a clean cleansing agent.*

HYDRAULIC OIL STRAINER *(Refer to Figure H-1.)*

The strainer is located inside the hydraulic oil tank in the suction line to the pump.

Periodically remove the strainer and clean it thoroughly.



463-564

Figure H-1. Hydraulic Oil Tank

TO CLEAN STRAINER:

1. Clean all dirt and dust from top of tank around suction line.
2. Remove cover plate, being careful not to damage gasket. Cover hole in tank to prevent foreign material from entering while strainer is being cleaned.
3. Detach strainer from suction line and remove end cap. Slide strainer enclosure off element.
4. Thoroughly clean and rinse strainer element and replace unit.
5. Reassemble strainer element and replace unit in tank. Be sure cover plate is sealed and tight.

RETURN LINE FILTER *(Refer to Figure H-3.)*

The return line filter is installed in the system to remove small impurities from the hydraulic oil.

Located on the face of the filter condition indicator gauge is a red band. The leading edge of this band is located at the point where the by-pass valve in the filter will open. When the filter is dirty, pressure will build up in the filter and open the by-pass valve, allowing dirty oil to by-pass the filter and return to the tank unfiltered. Therefore, when the needle on the gauge reaches this red band with the system operating, it is time to replace the filter element.

The element should be changed after the first 50 hours of operation. Thereafter, change the element when dirty as indicated by the gauge.

To change filter element, unscrew old element and replace.

HYDRAULIC PUMP

The hydraulic pump is a constant delivery, vane type. Field repairs to this unit are not advised. If the pump is proven to be defective, contact your dealer for factory assistance.

Figure H-2. Not applicable.

DIRECTIONAL CONTROL VALVE (Hopper Gate) *(Refer to Figure H-1.)*

MANUAL

The manual directional control valve is a four way, three position valve. This valve may be dismantled for cleaning and replacing "U" seal rings if necessary.

Figure H-3. Not applicable.

Page H-3. Not Applicable

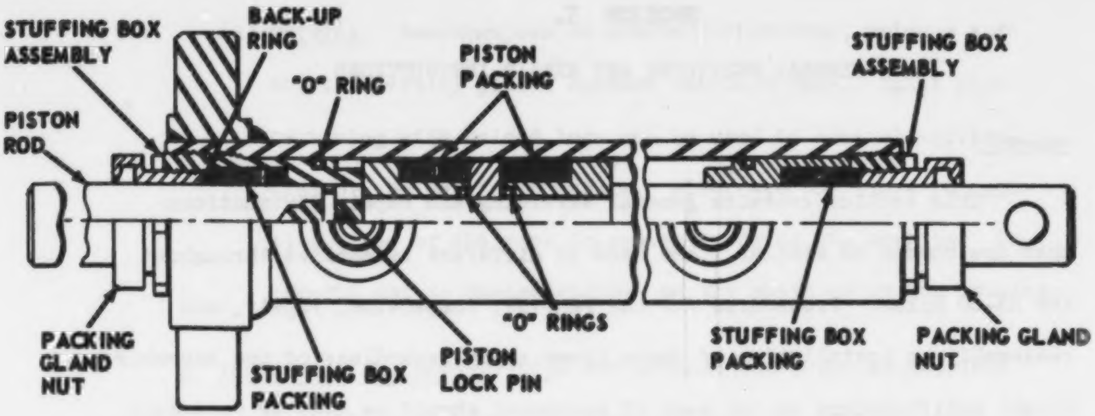

STUFFING BOX ASSEMBLY
BACK-UP RING
"O" RING
PISTON PACKING
STUFFING BOX ASSEMBLY
PISTON ROD
"O" RINGS
PACKING GLAND NUT
STUFFING BOX PACKING
PISTON LOCK PIN
STUFFING BOX PACKING
PACKING GLAND NUT

Figure H-4. Hydraulic Cylinder

HOPPER GATE RAM

The hopper gate ram used on the mixer is the double acting type with an adjustable packing gland nut.

For maintenance of this ram refer to sampling gate ram.

SECTION I.

GENERAL SERVICING AND REPAIR INSTRUCTIONS

GENERAL

This section contains general servicing and repair instructions that are common to similar items used in different assemblies throughout the KA-60 Mixer. Procedures for the removal, inspection, repair, and reassembly or installation of these items apply regardless of the assembly. Slight modifications on the part of personnel should be made as necessary to facilitate the work on any particular item.

BEARINGS

a. General. Bearings, when required, must be maintained in proper condition to prevent wear and misalignment of moving parts on which they are installed.

b. Removal. Bearings are usually a press fit on a shaft but occasionally they may be pressed in the bore of a bearing housing. When removing or installing a bearing on a shaft, always apply pressure on the inner race. When removing or installing in a bore, always apply the pressure on the outer race. Do not transmit lateral pressures through the bearing from one race to another.

(1) Pressing. Press bearings from shafts or out of housings whenever possible. Use firm steady pressure and do not allow the bearing shaft or housing to drop on the floor or ground.

(2) Pulling. Bearings may be pulled if a press is not available. The puller must be arranged to apply pressure on the retained race only.

(3) Driving. Bearings can be removed by driving, using a soft drift carefully placed against the held race. Split pipe or tubing with welded lugs can be used to control application of the driving pressure. Alternate the blows on opposite sides of the race to prevent wedging the bearing. Be careful not to damage splines on the shaft or in the housing.

c. Inspection and Repair. Wipe off as much lubricant as possible. Agitate bearing in clean solvent, being careful not to spin the races. Remove bearing from solvent and flat-slap bearing against a wood block to remove solvent and shake loose any coagulated lubricant. Place bearing back in clean solvent and continue agitating until all traces of old lubricant are removed. When bearing is clean, remove it from the solvent, shake out as much as possible, and blow dry with compressed air directed across the races. Do not allow the air to spin unlubricated balls or rollers in their races. As soon as the bearing is dry, dip it in clean, light oil to prevent corrosion, and continued contact of unlubricated bearing surfaces. Drain off excess oil and place bearing in a clean container or wrap until ready for inspection. The following defects cannot be rectified and require replacement of the bearings.

(1) Rust spots on balls or races.

(2) Worn or badly scored surfaces.

(3) Cracked race.

(4) Defective shield, seal, or separator.

(5) Badly discolored balls or races caused by overheating.

(6) Roughness.

(7) Bearing catching at one or more points caused by damage not by dirt.

(8) Excessive looseness or end play.

d. Installation. Clean shaft or housing before replacing a bearing. Pack the bearing with the proper lubricant. Install by pressing, the preferred method, or driving.

(1) Pressing. Apply pressure on the held race only. When pressing on a shaft, support the bearing so that the inner race takes the pressure, When installing in a housing, apply pressure against outer race. Use a suitable mandrel and blocks so that pressure is applied evenly around the race.

(2) Driving. When a press is not available, drive the bearing to its seat by using a soft drift against the held race. Alternate blows around the bearing to prevent cocking and possible wedging. Start bearing straight and be careful not to damage shaft or housing splines.

(3) Installation aids. Coating a shaft with lead before attempting to install pressfit parts will prevent binding and simplify installation. If necessary heat a very tight fitting bearing to 250°F. in a clean oil bath. Always clean, dry and repack bearings that have been preheated.

OIL SEALS

a. General. It is almost impossible to remove an oil seal without damaging it. Therefore, if a new seal is not immediately available, the old seal should be inspected in place.

b. Removal. Seals are removed by prying them out. They should then be discarded.

c. Inspection. Examine oil seals and discard if the following defects are observed: damaged case, worn sealing member, nicked sealing member, distorted inner diameter, or incorrectly seated seal.

d. Installation. New seals should always be inspected to assure that they are the right size. All burrs or sharp edges should be removed from the shaft to be sealed and the sealing element lubricated. The seal should be installed with the wiping edge of sealing element toward the lubricant or fluid to be sealed.

BUSHINGS

It is preferable to remove and replace bushings on an arbor press, which permits the pressure applied to be controlled and maintained square with the axis of the bore.

SHAFTS

A drift pin or block of wood should always be used to protect the end of a shaft when it requires hammering to drive it out or reinstall it. To avoid distortion and damage, never hammer directly on the end of any part.

GEARS

a. General. The same procedures of inspection and repair apply to all gears used throughout the KA-60 Mixer.

b. Inspection. Examine gears for cracked, scored, chipped or unevenly worn teeth. Examine the gear body for cracks and warpage. Inspect keyways for good condition.

c. Repair. Stone out small scored marks. Replace gears that have badly worn, chipped, or broken teeth. Small body cracks can be repaired by welding and grinding. The heated areas should be oil-quenched to maintain their heat treatment. Gear teeth or contact surfaces should be repaired by welding only if replacement parts are not available.

SHIMS

Shims are used to align and adjust bearings, bushings, gears, and shafts. Correct interaction of the machinery components requires the proper contact between parts, and this contact can be maintained only by shimming as the parts wear. When removing any part that is shimmed, mark carefully and tie the shims in their correct order for proper reassembly. If the shimming requirements of an assembly have changed, adjust the shims for the proper operation. Test run the unit after changing the shims to make certain that the shimming is correct before locking.

TROUBLE SHOOTING

GENERAL

This section provides information useful in diagnosing and correcting unsatisfactory operation or failure of the various components of the equipment. Each trouble symptom stated if followed by a list of probable causes of the trouble. The recommended remedy is described oppsite the probable cause.

BRAKES

a. Brakes Drag

Probable Cause	Possible Remedy
Clogged air tube or hose	Cleanout or replace obstructed part.
Wheel bearing out of adjustment	Adjust wheel bearings.

b. Brakes Take Hold Slowly

Probable Cause	Possible Remedy
Brakes out of adjustment	Adjust brakes.
Obstruction in air lines	Remove obstruction or replace.
Insufficient lubrication	Reference Lubrication Chart.

c. Brakes Do Not Apply

Probable Cause	Possible Remedy
Obstruction or broken tubing or hose-	Remove obstruction or replace.
Air Supply from towing vehicle not properly attached.	Attach air supply properly.
Slack adjuster out of adjustment	Adjust slack adjuster.

BITUMEN SYSTEM

a. Shear Bolt on Metering Pump Driven Sprocket Breaks Frequently

Probable Cause	Possible Remedy
Bitumen below pumping temperature	Increase bitumen temperature.
Sump strainer and/or spray bar nozzle-plugged creating excessive pressure	Remove strainer and/or nozzle and clean.
Insufficient or no hot oil pressure to keep bitumen at pumping temperature	Investigate hot heater system and increase output.

b. Insufficient Bitumen Coming from Spray Bar Nozzle

Probable Cause	Possible Remedy
Nozzle plugged or sump strainer clogged	Remove nozzle and/or strainer and clean.
Shear bolt on metering pump driven sprocket broken	Replace metering pump shear bolt.
Shear bolt on supply pump driven sprocket broken	Replace supply pump shear bolt.
Bitumen supply tank low or empty	Check bitumen supply tank level.

INSTRUMENTS

a. Revolution Counter Inoperative

Probable Cause	Possible Remedy
Improperly adjusted	Adjust revolution counter.
Linkage disengaged	Check linkage, attach and adjust.
Internal defect	Disconnect linkage and click counter by hand. Replace if defective.

b. Bitumen Temperature Thermometer Inoperative

Probable Cause	Possible Remedy
Glass broken or tube bent	Replace thermometer.
Internal defect	Check thermometer with one known to be correct. Replace if found defective.

BELT, CHAINS, AND BUCKET LINES

a. V-belts slip or Wear Out Quickly

Probable Cause	Possible Remedy
Belts not properly adjusted	Adjust belts.
Oil, grease or other foreign matter on belts	Remove belts and clean. Replace if necessary.
Belts rubbing against foreign object	Check area of belt travel and remove cause of wear.
Belts sheaves out of alinement	Aline belt sheaves.

b. Chains Excessively Noisy

Probable Cause	Possible Remedy
Improperly adjusted	Adjust chains.
Insufficient lubrication	Lubricate chains. Reference Lubrication Chart.

c. Chains Wear Out Rapidly

Probable Cause	Possible Remedy
Chains too tight or too loose	Adjust chains.
Sprockets out of line	Check sprocket alinement and adjust as necessary.

d. Bucket Line Noisy

Probable Cause	Possible Remedy
Too much slack in bucket line chains	Adjust bucket line tension.

Buckets loose	Tighten buckets to chain.
Bucket line too light	Adjust bucket line tension.

MIX

a. Mix Ignites in Pugmill

Probable Cause	Possible Remedy
Aggregate temperature too high	Decrease intensity of Dryer burner flame.
Bitumen temperature too high	Adjust hot oil temperature to bitumen supply tank and heat lines.

b. Emulsion Mix Breaking in Pugmill

Probable Cause	Possible Remedy
Aggregate temperature too high	Decrease intensity of Dryer burner flame.
Bitumen temperature too high	Adjust hot oil temperature to bitumen supply tank and heat lines.

c. Blue Fumes Rising From Mix

Probable Cause	Possible Remedy
Aggregate Temperature too high	Lessen intensity of Dryer burner flame.
Bitumen temperature too high	Adjust hot oil temperature to bitumen supply tank and heat lines.

d. Fluctuation of Bitumen Content in Mix

Probable Cause	Possible Remedy
Bitumen temperature too low	Increase hot oil temperature to bitumen supply tank and bitumen heating lines.
Metering pump driven sprocket shear	

bolt broken	Replace shear bolt.
Spray bar nozzle plugged	Remove nozzle and clean.
Leak in bitumen lines	Tighten loose connections.
Sump strainer clogged	Remove strainer and clean. (Remove strainer when using emulsions).

e. Too Much Bitumen in Mix

Probable Cause	Possible Remedy
Error in mix calculation	Review calculations to find error. Reference Mix Setup Instruction Manual.
Aggregate "arching over" in cold feeder hoppers	Work aggregate frequently to keep it loose.
Aggregate building up on cold feed hopper sides	Scrape aggregate from hopper sides.

f. Deficiency of Bitumen in Mix

Probable Cause	Possible Remedy
Error in calculation	Review calculations to find error. Reference Mix Setup Instruction Manual.
Fines percentage too great	Reduce fines feeder gate opening. Reference Mix Setup Instruction Manual.
Metering pump not set for proper percentage	Consult Pump Capacity Chart and set pump accordingly for correct percentage. Reference Mix Setup

Instruction Manual.

g. Change in Mix Appearance

Probable Cause		Possible Remedy
Excessive moisture in mix	-	Increase Dryer burner flame intensity decrease Dryer output to lessen moisture content.
Aggregate temperature too low	-	Increase Dryer burner flame intensity.
Aggregate temperature too high	-	Reduce Dryer burner flame intensity.
Bitumen temperature too high	-	Reduce hot oil temperature to bitumen supply tank and heat lines.
Bitumen timperature too low	-	Increase hot oil temperature to bitumen supply tank and heat lines.
Paddle arm tips worn out	-	Reverse or replace paddle arm tips.

h. Aggregate Particles Not Coating Properly

Probable Cause		Possible Remedy
Excessive moisture in mix	-	Increase Dryer burner flame intensity or decrease Dryer output to lessen moisture content.
Aggregate temperature too low	-	Increase Dryer burner flame intensity or decrease Dryer output to raise aggregate temperature.

PUGMILL

a. Machine Labors During Pugmill Operation

Probable Cause	Possible Remedy
Too much mix permitted to remain in pugmill	Adjust pugmill dam gate.
Paddle arms not set properly	Adjust paddle arms. Refer to Pugmill Paddle Settings.

b. Paddle Tips and Liner Plates Wear Out Rapidly

Probable Cause	Possible Remedy
See a above	See a above.

DISASSEMBLY AND REPAIR

TORQUE ARM REDUCER

a. **Removal**. Refer to Figure I-1 and remove torque arm reducer as illustrated.

b. **Disassembly**.

(1) Refer to Figure I-2 and drain lubricant from housing .

(2) Remove top cover and end plates.

(3) Remove bearing retainers, bearing cups and shims.

(4) Using suitable puller remove bearing cone and rollers and remove pinion shaft, 84 tooth gear, and 12 tooth spur gear.

c. **Inspection and Repair**.

(1) Clean all parts with an approved cleaning solvent and dry thoroughly.

(2) Inspect all parts for wear or damage and replace damaged or defective parts as necessary.

d. **Reassembly**. Reverse disassembly procedure in b above.

e. **Installation**. Refer to Figure I-1 and install torque arm reducer as illustrated.

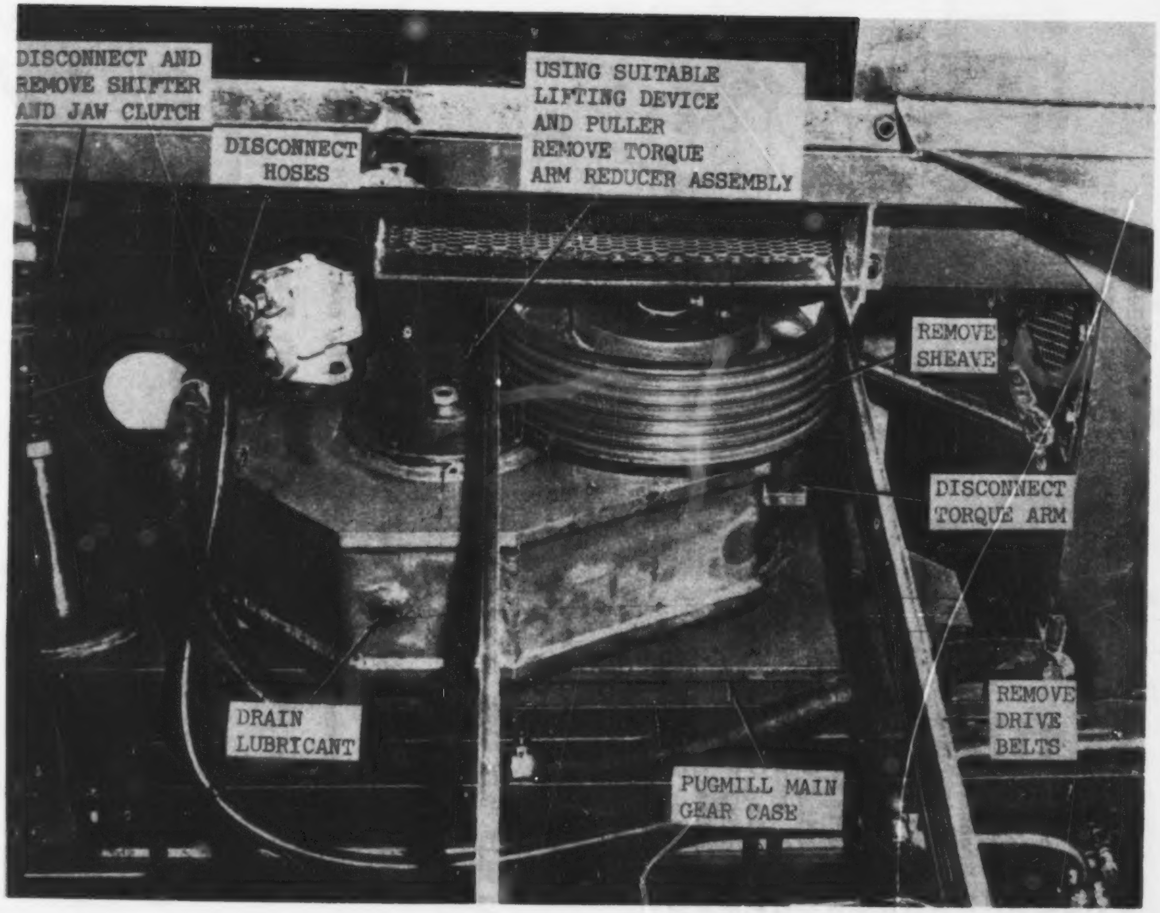

DISCONNECT AND
REMOVE SHIFTER
AND JAW CLUTCH
DISCONNECT
HOSES
USING SUITABLE
LIFTING DEVICE
AND PULLER
REMOVE TORQUE
ARM REDUCER ASSEMBLY
REMOVE
SHEAVE
DISCONNECT
TORQUE ARM
DRAIN
LUBRICANT
REMOVE
DRIVE
BELTS
PUGMILL MAIN
GEAR CASE

Figure I-1. Torque arm reducer, removal and installation.

4 Gear Housing
5 Gasket
6 Cover
8 Repair Plate
9 Drive Screw
10 Reducing Bushing
11 Breather Filter
12 Magnetic Drain Plug
13 Gear Case Oil Gauge
21 Bearing Cartridge
23 Shim
26 Bearing Cup
27 Bearing Cone and Rollers
29 17T. Spur Pinion Shaft
31 Bearing Cone and Rollers
32 Bearing Cup
33 Oil Seal
34 Bearing Cartridge
36 Shim
49 Oil Seal
50 Bearing Retainer
52 Bearing Cup
53 Bearing Cone and Rollers
55 Sleeve
56 84 T. Spur Gear
57 Key
59 Spacer
60 Shim
63 Bearing Cup
64 Bearing Cone and Rollers
65 End Cap
67 Shim
68 End Cap
73 End Cap
74 Gasket
76 Bearing
77 12 T. Spur Gear

Figure I-2. Torque arm reducer assembly.

PUGMILL MAIN GEAR CASE

a. Disassembly.

(1) Remove torque arm gear reducer Figure I-1.

(2) Disconnect elevator drive slipshaft, and remove shifter lever, hub and jaw clutch from shaft Figure I-1

(3) Refer to Figure I-3 and drain lubricant from gear case.

(4) Remove top cover, seal plates, end caps, bearing retainers, and bearing cups and shims.

(5) Using suitable puller remove bearing cone and rollers and remove 50 tooth spur gears from pugmill shafts.

(6) Remove input pinion shaft and elevator drive clutch shaft.

IMPORTANT. Before removing 50 tooth spur gears, the position of the pugmill shafts, relative to each other, and the position of the gears should be marked so that they can be reassembled as before, to maintain proper timing of the pugmill paddle shafts.

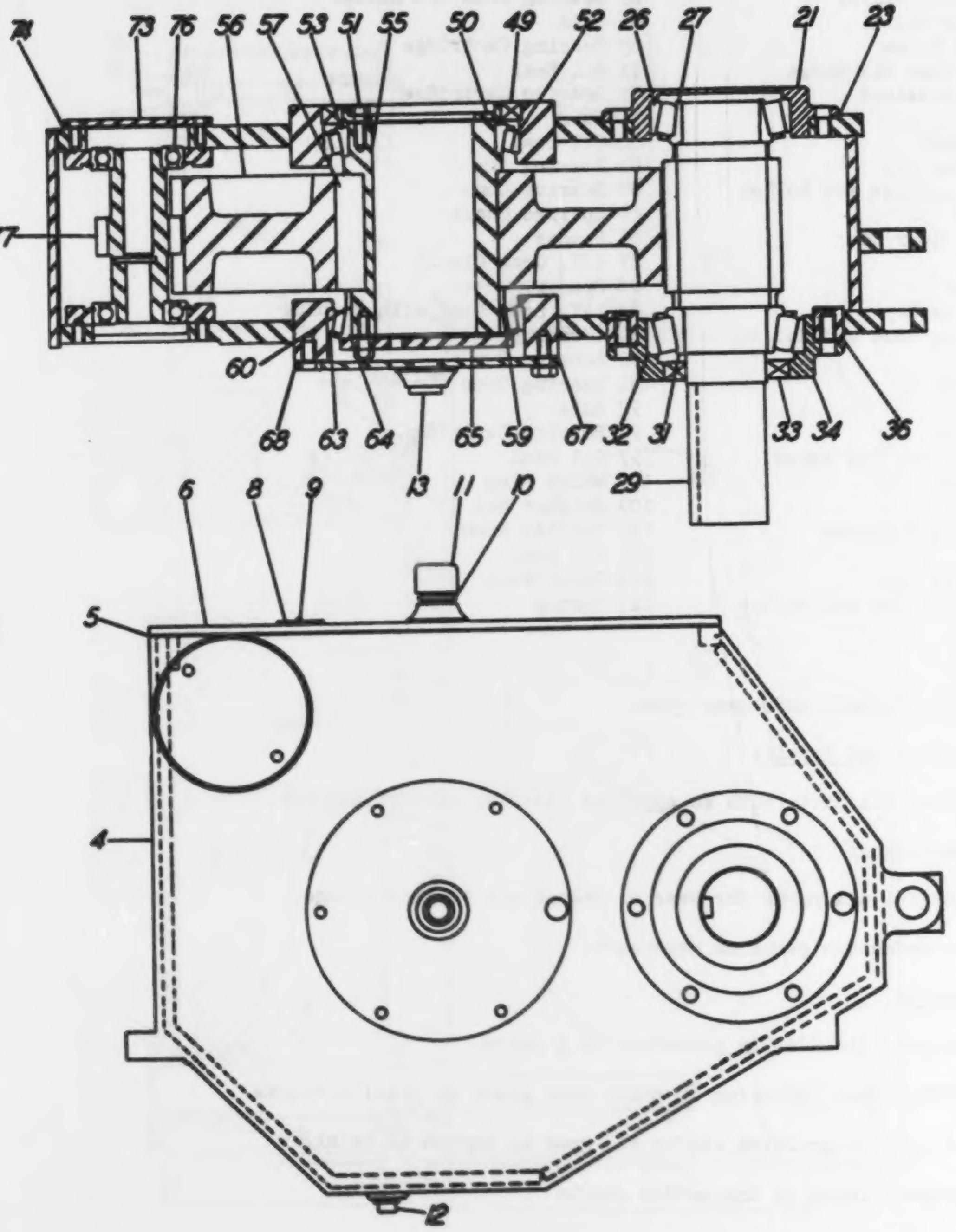

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Figure I-2. Torque arm reducer assembly.

4 Gear Housing
5 Cover
6 Gasket
8 Breather Filter
9 Repair Plate
10 Drive Screw
11 Gear Case Oil Gauge
16 Seal Retainer
17 Shim
21 Oil Seal
22 Bearing Cup
23 Bearing Cone and Roller
25 Shaft
27 14 T. Spur Gear
28 Key
29 Spacer
30 Bearing Cup
31 Bearing Cone and Roller
32 Shim
35 End Cap
46 Shim
47 End Cap
48 Socket Hd. Cap Screw
49 End Cap
50 Gasket
52 Bearing Retainer
53 Shim
57 Bearing Cup
58 Bearing Cone and Roller
60 Hub
61 50 T Spur Gear
62 Key
64 Bearing Cup
65 Bearing Cone and Roller
66 Shim
69 Bearing Cartridge
71 Oil Seal
75 Bearing Cartridge
76 Shim
80 Oil Seal
81 Bearing Cup
82 Bearing Cone
84 Splined Shaft
86 Spacer
87 27T. Gear Clutch
88 Spacer
89 14T. Spur Gear with Bushing
89A Bushing
90 Bearing Cup
91 Bearing Cone and Rollers
92 Shim
95 Bearing Cartridge
97 Oil Seal
108 Welch Plug
109 Shifter Rod
110 Shifter Fork
111 Oil Seal
112 Steel Ball
113 Spring

Figure I-3. Pugmill main gear case.

b. Inspection and Repairs

(1) Clean all parts with an approved cleaning solvent and dry thoroughly.

(2) Inspect all parts for wear or damage and replace damaged or defective parts as necessary.

c. Reassembly

(1) Reverse disassembly procedure in a above.

(2) NOTE: When replacing 50 tooth spur gears on pugmill shafts be sure to position shafts and gear as marked to maintain proper timing of the paddle shafts.

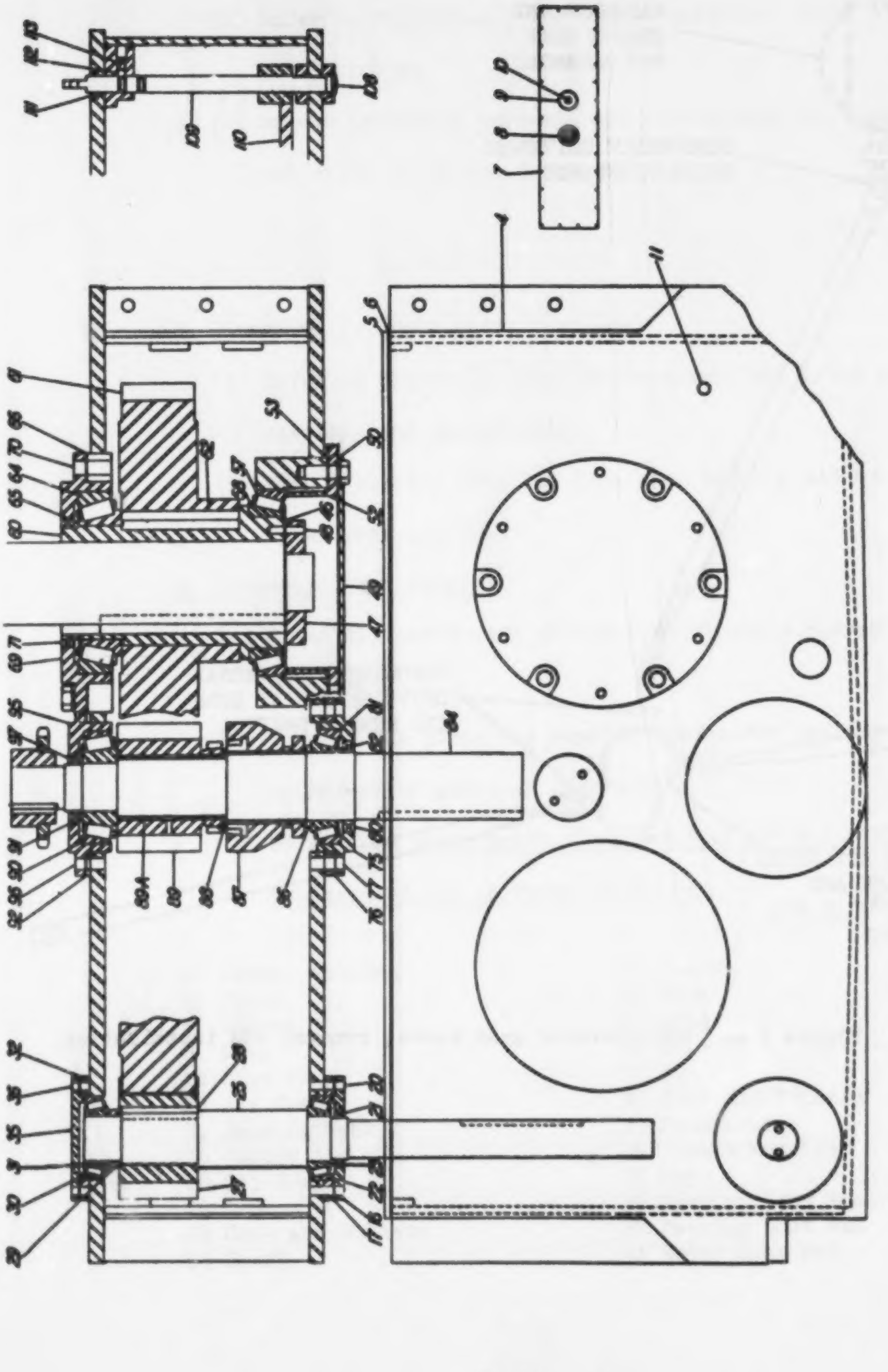

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Figure I-3. Pugmill main gear case.

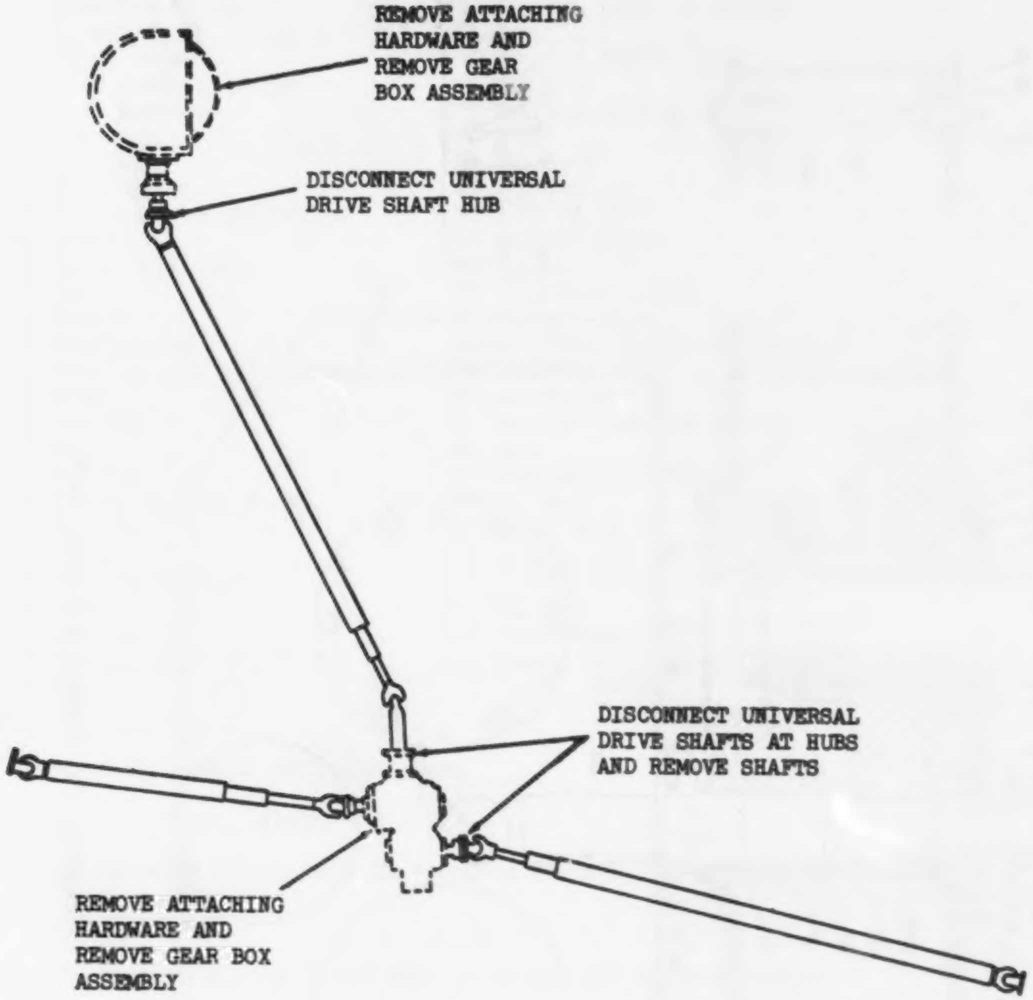

REMOVE ATTACHING HARDWARE AND REMOVE GEAR BOX ASSEMBLY
DISCONNECT UNIVERSAL DRIVE SHAFT HUB
DISCONNECT UNIVERSAL DRIVE SHAFTS AT HUBS AND REMOVE SHAFTS
REMOVE ATTACHING HARDWARE AND REMOVE GEAR BOX ASSEMBLY

Figure I-4. Hot elevator gear boxes, removal and installation.

HOT ELEVATOR GEAR BOXES

a. Removal

(1) Refer to Figure I-4, disconnect universal drive shafts at gear box hubs.

(2) Remove attaching hardware and remove gear box assemblies and drain lubricant from gear cases.

b. Disassembly. (Head shaft Gear Box)

(1) Refer to Figure I-5 and remove sleeve and bevel pinion shaft assembly and disassemble.

(2) Remove bearing retainer from gear housing and remove large bevel gear and hub.

c. Inspection and Repair.

(1) Clean all parts with an approved cleaning solvent and dry thoroughly.

(2) Inspect all parts for wear or damage and replace damaged or defective parts as necessary.

NOTE: The bevel gears are a matched set and both must be replaced if one is found defective.

4 Trans. Housing
5 Cover
6 Gasket
8 Plug
11 Pipe Plug
12 Air Vent
15 Bearing Seal
16 Gasket
18 Oil Seal
20 Cup
21 Cone and Rollers
23 Shaft

25 Sleeve
27 Shim
28 Shim
29 Shim
31 Cup
32 Cone and Rollers
33 Shim Washer
34 Grease Retainer
35 Key
36 Bearing Lock Washer
37 Bearing Lock Nut
41 Bevel Gear Set

47 Oil Seal
49 Bearing Retainer
50 Shim
51 Shim
52 Shim
53 Cup
54 Cone and Rollers
55 Key
57 Spur Pinion Shaft
59 Oil Slinger
60 Cup
61 Cone and Rollers
62 Bearing Retainer
63 Shim
64 Shim
65 Shim
70 Bearing Retainer
71 Shim
72 Shim
73 Shim
75 Cup
76 Cone and Rollers
78 Shaft
80 Spur Gear
81 Key
82 Cup
83 Cone and Roller
84 Bearing Retainer
85 Shim
86 Shim
87 Shim
89 Oil Seal

A - Intermediate gear box.

1 Shim
2 Shim
3 Shim
4 Bearing Retainer & Support
5 Cup
6 Cone and Roller
7 Hub
8 Oil Seal
9 Bevel Gear (pair)
10 Thrust Bolt
11 Sleeve
12 Cup
13 Cone and Roller
14 Lock Nut
15 Lock Washer
16 Key
17 Oil Seal
18 Retainer
19 Gasket
20 Shim
21 Shim
22 Shim
23 Oil Flingers
24 Retainer
25 Repair Plate
26 Drive Screw
27 Gasket
28 Drain Plug
29 Gear Box
30 Pipe Cap
31 Pipe Nipple
32 Cover

B - Head shaft gear box.

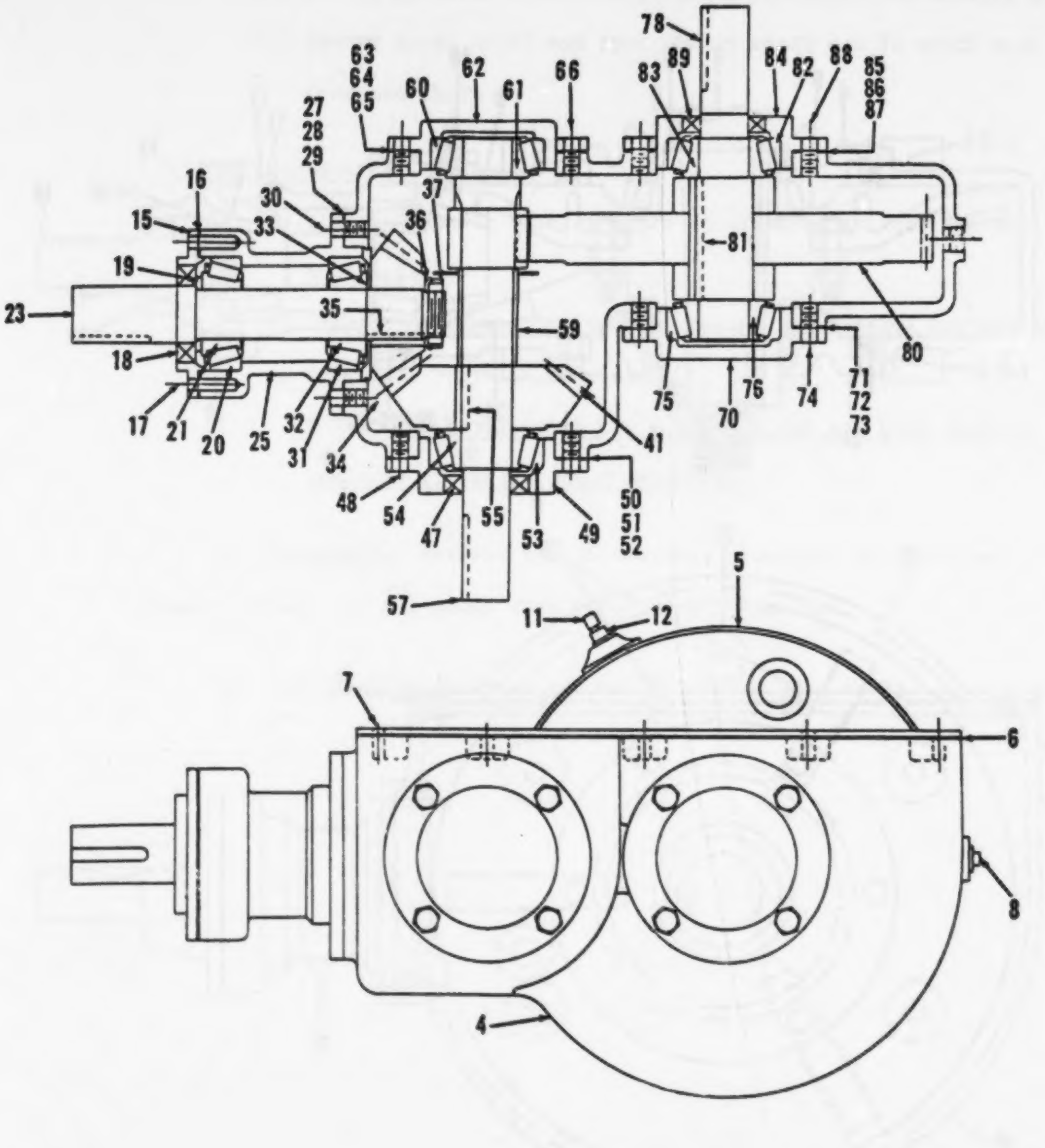
Figure I-5. Hot elevator gear box assemblies.

d. Reassembly. Reverse the disassembly prcedure in b above. Always install new oil seals when rebuilding a gear box.

e. Installation. Reverse removal procedure in a above.

aa. Disassembly. (Intermediate Gear Box)

(1) Refer to Figure I-5 and remove sleeve and bevel pinion shaft assembly and dismantle.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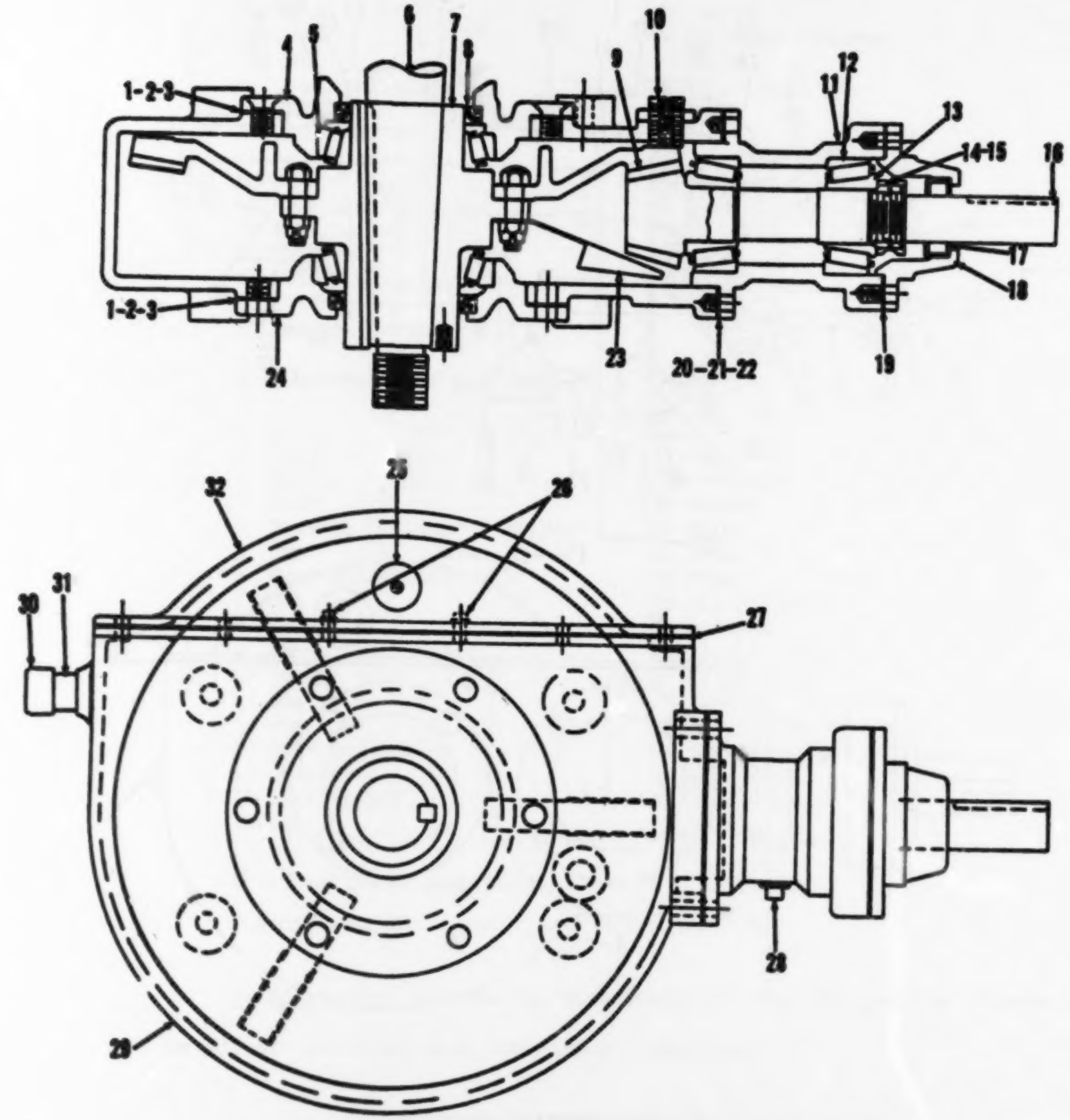
A - INTERMEDIATE GEAR BOX

Figure I-5. Hot elevator gear box assemblies.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B - HEADSHAFT GEAR BOX a (6 to 1) ASSEMBLY

Figure I-5. Hot elevator gear box assemblies, continued.

(2) Remove oil seal retainers, bearing retainers and bearing cups.

(3) Remove input bevel and spur pinion shaft and 72 tooth spur gear and shaft.

bb. Inspection and Repair.

(1) Clean all parts with an approved cleaning solvent and dry thoroughly.

(2) Inspect all parts for wear or damage and replace damaged or defective parts as necessary.

NOTE: The bevel gears are a matched set and both must be replaced if one is found defective.

cc. Reassembly. Reverse the disassembly procedure in aa above. Always install new oil seals when rebuilding a gear box.

dd. Installation. Reverse removal procedure in a above.

APRON FEEDER SINGLE AGGREGATE

The aggregate hopper and apron feeder are mounted on the Hot Elevator.

The hopper is equipped with a mechanical bin level telltale with an electric warning system and a hopper overflow chute.

The apron feeder, mounted under the hopper, provides aggregate flow through a calibrated gate. The opening of the gate is adjusted by a screw and ratchet lever. The gate is raised to increase and lowered to decrease the aggregate flow. It can be padlocked after being set at the desired opening.

The apron feeder is chain driven from the Hot Elevator and interlocked with the asphalt metering pump to deliver the correct amount of aggregate to the spray chamber.

AGGREGATE TEST GATE *(Refer to Figure J-1.)*

The test gate and spout below the apron feeder are arranged so samples of aggregate can be taken while the machine is in operation without interfering with the operation. This provides a convenient means of calibration and checking.

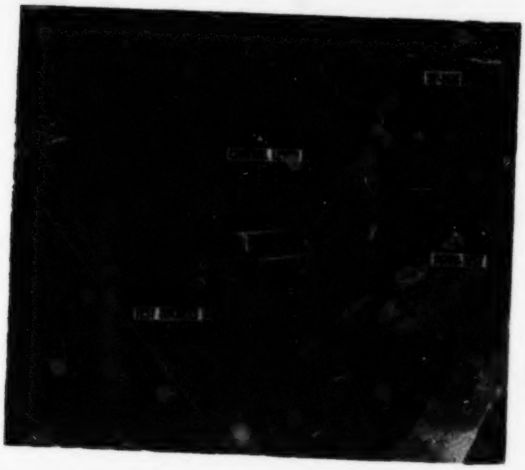

Figure J-1. Aggregate Test Gate Control Lever

The test gate lever controls the gate, directing the flow of aggregate as it leaves the apron feeder. Depending upon which position the lever is set, aggregate will flow out the test spout or into the hot elevator.

1. Move the lever down to discharge material out the test spout.
2. Move the lever up to discharge material into the hot elevator.

CALIBRATED CONTROL GATE *(Refer to Figure J-2.)*

The opening of the calibrated gate is adjusted by screws and a ratchet lever. The gate is raised to increase and lowered to decrease the aggregate flow. A calibrated scale and pointer shows the height of opening in inches and fractions of an inch. The gate can be padlocked after being set at the desired opening.

APRON FEEDER ERECTION

1. Lift the feeder into position and mount forward end on the hot elevator with the rear support legs on the ground.
2. Install the feeder drive chain and adjust idler.
3. Install the feeder drive chain guard.

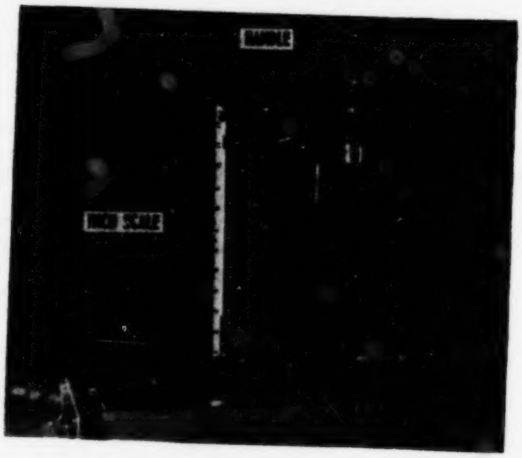

Figure J-2. Apron Feeder Gate

CALIBRATING APRON FEEDER GATE

In calibrating, the test buckets are filled with dried aggregate from the apron feeder. The net weight of the aggregate is divided by the number of revolutions the apron feeder turned delivering this aggregate. This gives the pounds of aggregate delivered per revolution of the apron feeder.

The apron feeder speed can be changed by the use of a different driver sprocket. Refer to MAINTENANCE, this section.

1. Start Dryer operating. *(Refer to Dryer OSM).*
2. Set apron feeder control gate at 2" opening.
3. Fill hopper with dried aggregate. Check bin level indicator light.

    ***NOTE:** Once the light goes on, it will will not go out until sufficient material is run through to cause the arm to lift.*

4. Weigh test buckets and record weight.
5. With test gate control lever in "Run" position, operate pugmill and apron feeder for 2 3 revolutions. This will enable material to flow through the gate long enough to give the effect of the 2" gate opening to the end of the apron feeder without having aggregate drop into the test buckets.
6. Stop apron feeder and turn test gate lever to "Test" position.
7. Take initial revolution counter reading and record it.
8. Run apron feeder long enough to fill test buckets about 3/4 full. Be careful not to stop and start apron feeder during test. Run continuously until desired amount of material is in test bucket.
9. Record the final revolution counter reading and subtract the initial reading from it to determine the number of revolutions used in the test.
10. Weigh test buckets carefully and subtract the weight of the empty buckets to get the weight of the aggregate.
11. Divide the weight of the aggregate by the number of revolutions run to get the pounds per revolution delivered from a 2" gate opening.
12. Repeat the above procedure for a series of gate openings. When changing gate openings, be sure to run feeders long enough to bring material struck off at the new gate opening to the point of discharge from the feeder.
13. With the aggregate flow determined at various gate settings, plot these points on graph paper (pounds per revolution against inches of gate opening) and connect these points with a line. This chart is then used to set feeder gate per mix specifications.

MAINTENANCE

APRON FEEDER SPEED CHANGE SPROCKETS *(Refer to Figure J-3.)*

Two speed change sprockets are furnished with the mixer. The larger the sprocket, the higher the feeder speed. Therefore, with the larger sprocket, smaller gate openings may be used.

TO CHANGE SPROCKET:

1. Loosen bolts (A) on the take-up idler.
2. Remove the chain from the speed change sprocket.
3. Loosen the set screw (B) on the speed change sprocket.
4. Pull the sprocket and install the desired sprocket.
5. Tighten the set screw, replace the chain, and adjust the idler for proper chain tension.

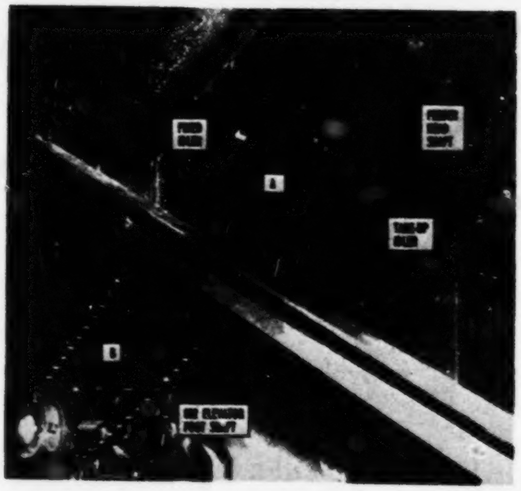

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Figure J-3. Apron Feeder Drive Chain

APRON FEEDER DRIVE CHAIN *(Refer to Figure J-3.)*

This chain is adjusted by moving the idler sprocket mounted in the chain guard on the return side of the chain.

TO ADJUST CHAIN:

1. Remove chain guard.
2. Loosen nuts and move idler upward until proper chain tension is obtained.
3. Tighten nuts and replace chain guard.

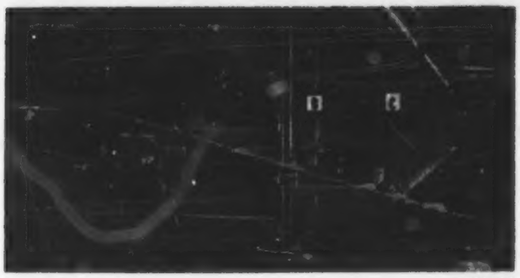

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Figure J-4. Apron Feeder Chain

If more adjustment is needed, the bolts can be put in a different set of holes, or a link can be removed from the chain.

APRON FEEDER CHAIN *(Refer to Figure J-4.)*

The apron feeder chain should be adjusted when the maximum point of sag on the slack run reaches approximately 1".

TO ADJUST CHAIN:

1. Loosen lock nuts (B) on take-up bolts (C). One on each side of feeder.
2. Turn bolts (C) the same amount on each side until proper tension is obtained.
3. Tighten lock nuts (B).

The apron feeder should be checked periodically for worn or bent flights.

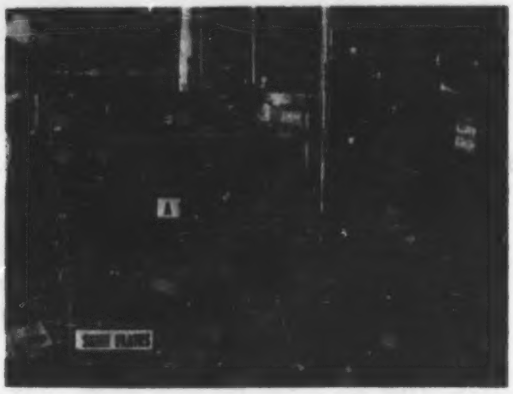

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Figure J-5. Apron Feeder Skirt Plates

APRON FEEDER SKIRT PLATES *(Refer to Figure J-5.)*

The apron feeder is equipped with skirt plates to prevent aggregate from leaking off the side of the apron.

TO ADJUST PLATES:

1. Loosen bolts (A) and push plates down. Allow 1/16" clearance between skirt plates and apron feeder plates.
2. Tighten bolts.

PART II

DIESEL ENGINE

(ALLIS CHALMERS MODEL 3500)

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HOW TO USE THIS MANUAL TO BEST ADVANTAGE

The manner in which you operate the engine and the maintenance you perform on it will have much to do with its performance and durability. Of equal importance is the use of proper procedures during engine overhaul. This manual has been carefully prepared and the information arranged and illustrated to make it as easy as possible for you to find the information you need regarding proper operation and maintenance. Before operating, performing maintenance, or beginning a repair/overhaul, read the manual carefully to familiarize yourself with the procedures involved, as well as the equipment with which you are concerned. Keep this manual handy and refer to it often.

The manual consists of 17 SECTIONS covering the subjects listed in the TABLE OF CONTENTS immediately preceding this article. Each SECTION is divided into TOPICS that differentiate between various subjects within a SECTION. Each TOPIC is further divided into PARAGRAPHS when more than one particular subject is dealt with in a TOPIC. To find a TOPIC on any subject in the manual, turn first to the TABLE OF CONTENTS. Note the SECTION number in large print opposite the SECTION title in which you are interested. This SECTION number registers with a tab printed on an INDEX page preceding the first page of each SECTION. Read the titles on the SECTION INDEX page. Find the specific information you want by turning to the TOPIC indicated in bold print. SECTION/TOPIC numbers appear in the lower outside corner of each page.

SECTION———→ 7.4 ←———TOPIC
Page 5

EXAMPLE: To find information pertaining to valve seat grinding, turn to the TABLE OF CONTENTS and note the subject titled VALVES, VALVE OPERATING MECHANISM, AND CYLINDER HEAD. Number 7 (the SECTION number) appears in bold print opposite this SECTION title. Turn to the beginning of SECTION 7 which is marked by tab number 7. An examination of the list of topics on this page shows that TOPIC 4 concerns valves, and that PARAGRAPH D, gives specific instructions in valve face and valve seat grinding. Turn the pages to SECTION/TOPIC 7.4. On Page 5 is found PARAGRAPH F, titled VALVE FACE AND VALVE SEAT GRINDING.

SECTION CONTENT

SECTION 1 of the manual contains a general description of the engines, engine systems, and engine subassemblies, e.g., Turbocharger, Lubrication System, Cooling System, Air Cleaner, Electrical System, etc. Also included are Maintenance and Operating Instructions, Specifications, Troubleshooting, Fits and Tolerances, etc. SECTIONS 2 through 17 contain specific instructions for the removal, assembly, inspection, and overhaul of the engines and subassemblies, plus items of optional equipment.

PAGE NUMBERS

Pages are numbered consecutively, starting with a new Page 1 at the beginning of each TOPIC. The page number appears below the SECTION/TOPIC number in the lower outside corner of each page.

ILLUSTRATION NUMBERS

Illustrations are numbered consecutively, beginning with a new Figure 1 in each TOPIC.

SECTION 1
OPERATING AND MAINTENANCE INSTRUCTIONS
POWER UNITS

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3 PREPARATION OF ENGINE FOR OPERATION 1.3
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TOPIC 1. GENERAL DESCRIPTION

Engine Models 3500 are 4 cycle, water cooled, overhead valve, compression-ignition type diesel engines with 6 vertical in-line cylinders and a turbocharger.

The basic engine, engine assemblies, and power units have been engineered with equipment necessary for usual installation requirements. All units can be modified for various applications by addition of optional equipment.

Engines shipped from Allis-Chalmers Manufacturing Company are equipped with an optional equipment plate, Figure 1. Catalog numbers of the various optional equipment groups as specified on the original factory order, are listed on the plate, together with the specific factory shipping order number.

> NOTE: Furnishing of pertinent data regarding operation and maintenance of equipment not originally supplied by the Allis-Chalmers Manufacturing Company is the responsibility of the company that assembles the equipment to the engine.

The engine serial number, model number, and engine part number are stamped on the name plate, Figure 2, located on the left rear side of the cylinder block.

> NOTE: To obtain shipment promptly when ordering repair parts, always give the information on the engine name plate, and the repair part number and name. Order parts from the dealer covering the local territory.

A. PRINCIPLES OF OPERATION

The fuel system consists of a combination primary and secondary fuel filter, differential needle type fuel injection nozzle holder assemblies, and a fuel injection pump with an integral fuel transfer pump and governor. The system cleans, prepares, and delivers accurately metered quantities of fuel under high pressure to the engine cylinders where it is ignited by heat of air compressed in the cylinders.

Proper lubrication is assured by a gear type lubricating oil pressure pump driven by a camshaft gear. Dual, full flow type oil filters with disposable filter elements keep the main oil gallery supplied with clean lubricating oil. Oil is pumped under 45 to 50 psi pressure from the main oil gallery to the crankshaft, connecting rods, idler gear, and rocker arm assembly. All other internal moving parts are lubricated by splash, spray, and oil in suspension.

A Thompson 370 Series turbocharger is used to obtain greater power output of Model 3500 diesel engines.

The 370 Series turbocharger is essentially a rugged yet highly efficient exhaust driven blower.

The turbocharger responds to engine load demands by reacting to the flow of expanding exhaust gases and supplying a correlated volume of air to engine cylinders. During a heavy load/lugging operation, the increased flow of exhaust gases turns the turbine wheel faster, causing the compressor impeller to turn faster to supply more air to the intake manifold. Conversely, when engine load is light and the radial flow of gases within the turbine decreases, the turbocharger compressor reduces air supply to the intake manifold.

B. ENGINE STROKE SEQUENCE

In a 4 cycle diesel engine, a power stroke is made by each piston every two complete revolutions of the crankshaft. Sequence of strokes is intake, compression, power, and exhaust.

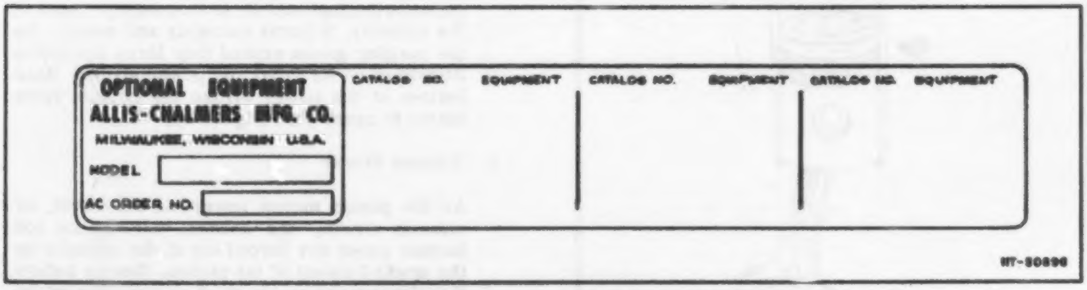


Figure 1. Engine Optional Equipment Plate

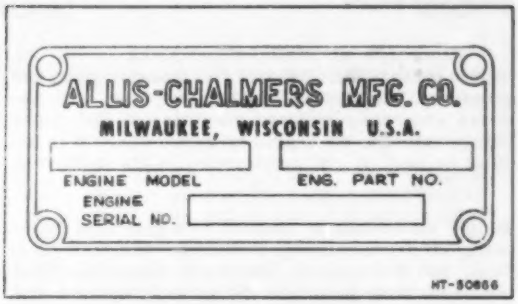


Figure 2. Engine Name Plate

1. Intake Stroke

   As the piston moves downward on the first, or intake stroke, air enters the cylinder through the air intake manifold and intake valve, which starts to open a few degrees before the piston reaches top dead center. The intake charge, consisting of air only, rushes into the cylinder and is given a swirling motion by directional ports in the cylinder head. (See Figure 3.)

2. Compression Stroke

   Shortly after the piston starts to move upward on the second, or compression stroke, the intake valve closes. The swirling motion of air admitted on the intake stroke is intensified during the compression stroke and its temperature is raised to approximately 1000°F. The contoured piston top compresses and simultaneously forces the air toward its center, giving it an additional rolling motion and greater velocity. At the proper instant during the compression stroke, a metered quantity of fuel is injected into the combustion chamber in a four-jet pattern under extremely high pressure. When the finely atomized fuel has mixed thoroughly with the turbulent air it is ignited by heat of the compressed air and immediately starts to burn. (See Figure 4.)

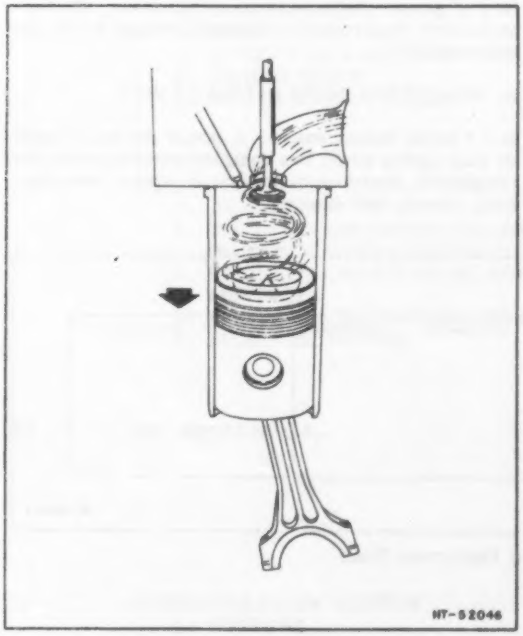


Figure 3. Intake Stroke

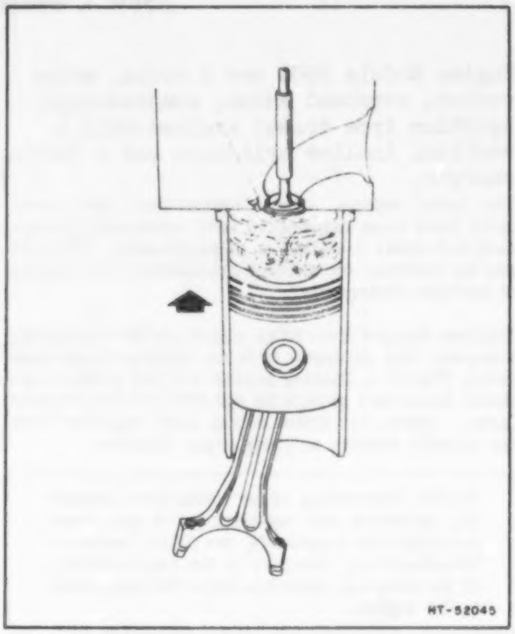


Figure 4. Compression Stroke

3. Power Stroke

   Because the fuel and air is thoroughly mixed in the cylinder, it burns smoothly and evenly. As the burning gases expand they force the piston downward on its third, or power stroke. Near bottom of the power stroke the exhaust valve starts to open. (See Figure 5.)

4. Exhaust Stroke

   As the piston moves upward on the fourth, or exhaust stroke, the exhaust valve opens and burned gases are forced out of the cylinder by the upward travel of the piston. Shortly before the piston reaches top dead center, the intake valve starts to open to admit a fresh charge of air to the cylinder. A few degrees after the piston reaches top dead center, the exhaust valve closes completely, denoting the end of one cycle and beginning of the next. (See Figure 6.)

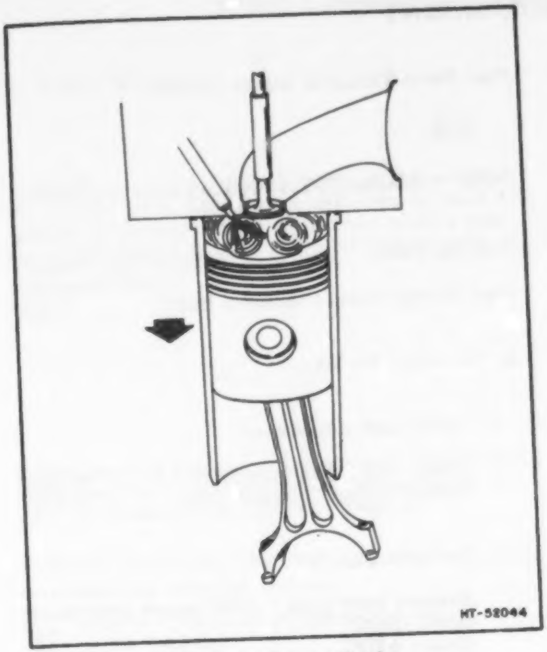


Figure 5. Power Stroke

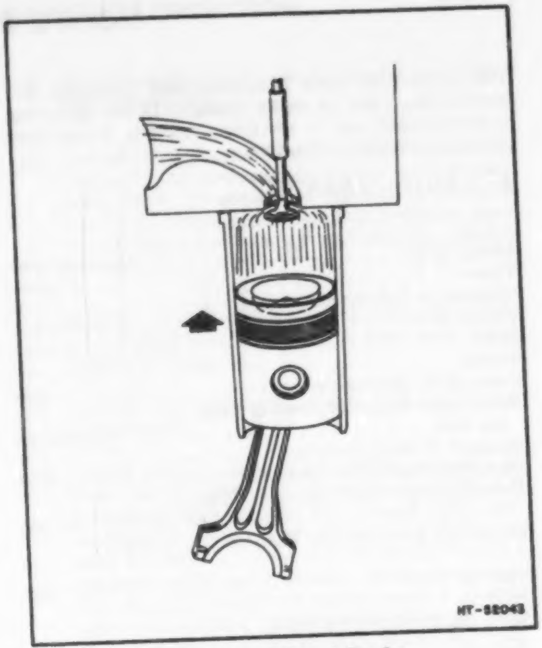


Figure 6. Exhaust Stroke

TOPIC 2. SPECIFICATIONS

The Allis-Chalmers Manufacturing Company reserves the right to make changes in the following specifications and to add improvements at any time without notice or obligation.

A. ENGINE (BASIC)

Model 3500	Turbocharged
Type	4 cycle
Number of Cylinders	6
Firing Order	1-5-3-6-2-4
Bore	4-1/4"
Stroke	5"
Cubic Inch Displacement	426
Crankshaft Rotation (viewed from fan end)	Clockwise
Number of Main Bearings	7
Compression Ratio (nominal)	16:1
Compression Pressure at Sea Level, 600 rpm, hot	500 psi + or - 15 psi
Maximum Permissible Exhaust Restriction:	
Model 3500	1" Hg.

B. COOLING SYSTEM

Stabilized Coolant Temperature (minimum)	180°F
Water Pump Type	Centrifugal, Belt Driven
Radiator, Pressurized	7 psi
Nominal Capacities:	
Model 3500, engine only	18.5 qts
Model 3500, radiator and hoses	15.5 qts

C. LUBRICATING SYSTEM

Type System	Full Flow, Circulating Pressure
Oil Pump Type	Gear, Positive Displacement
Oil Pressure Range, hot, at full throttle	30 - 55 psi
Pressure regulation governed by	Regulation Valve
Nominal Oil Capacity:	
Model 3500 Filters and Oil Change	13 qts
Lubricating Oil Filters	Dual Full Flow
Maximum Angle of Operation	15°

D. FUEL INJECTION SYSTEM

Nozzle Holder Assembly Mfr	Allis-Chalmers
Fuel Injection Pump Mfr	Roosa Master
Nozzle Type	Spring Loaded, Four Hole Orifices
Opening Pressure:	
Model 3500	2900 psi
Orifice Size:	
Model 3500	0.32 mm (0.0126")

Fuel Pump Timing to Engine (static):

RPM	
1800 - 2000	34°BTDC

Fuel Oil Filter	Combination, Primary and Secondary
Hand Primer Pump (maximum lift)	6 feet

E. VALVE DATA

1. Valve Lash Adjustment

Intake Valve Clearance (hot)	0.015"
Exhaust Valve Clearance (hot)	0.015"

2. Valve Timing

Exhaust Valve (with 0.0195" tappet clearance):	
Opens BBDC	56°
Closes ATDC	16°
Duration	252°
Intake Valve (with 0.0195" tappet clearance):	
Opens BTDC	20°
Closes ABDC	48°
Duration	248°

CAUTION: Tappets must be set with 0.0195" clearance to obtain proper valve opening and closing in degrees tabulated for the camshaft. Do not confuse this setting with valve lash adjustment data.

F. GOVERNOR (mechanical)

Type	Variable Speed, Flyball
Regulation (standard)	10%
Regulation (optional)	3-1/2%
Speed (standard setting):	
Full Load	1800 rpm
High Idle (no load)	1980 rpm
Low Idle	500 - 600 rpm

G. U.S. to METRIC MEASURE CONVERSION FACTORS

Pints x 0.4732 = Liters . . . . Gallons x 3.7853 = Liters

Quarts x 0.9463 = Liters . . . . Pounds x 0.4536 = Kilograms

TOPIC 3. PREPARATION OF ENGINE FOR OPERATION

A. PROCEDURE

For your protection, make a thorough inspection of the engine immediately upon delivery. In case of damage or shortage, have the carrier make a notation on the freight bill and notify the transit agent at once.

Before starting the engine the operator should fully understand the use and function of the operating controls and instruments. (Refer to Topic 4.)

Before starting the engine, perform the operations listed below.

1. Remove all tape and shipping caps used to seal engine openings.
2. Check radiator for damage incurred during shipment. Remove any foreign material that has collected on the radiator during shipment to prevent it from obstructing air flow around fins and between passages of the radiator.
3. If drain plugs have been removed and wired to to the engine, install them properly.
4. Make certain all air cleaner connections are tight to prevent dirt being drawn into the engine cylinders.
5. Check oil level in oil pan with the dipstick.

> NOTE: The engine is shipped with Service DS (Series 3), SAE 20 weight lubricating oil. Maintain proper oil pan level with any good quality Service DS oil. The factory oil is compatible with any Service DS oil supplied by any major oil company. At the first regular oil change period (100 hours), drain factory oil and fill with proper classification and SAE weight of oil for the prevailing atmospheric temperature. (Refer to Topic 6.)

6. Fill cooling system with coolant. (Refer to Topic 11.)
7. Check engine drive belts for correct adjustment. Deflection should be 1/4" to 1/2" for the pair of belts. (Refer to Topic 11.)
8. Connect storage battery to the electrical system. (Refer to Topic 14.)
9. Fill fuel tank with the recommended fuel. (Refer to Topic 7.)
10. Connect fuel supply line from fuel tank to the fuel sediment bowl connected to the hand primer pump inlet. Connect fuel and nozzle overflow line to top of fuel tank. Open fuel sediment bowl shutoff valve and vent the fuel system. (Refer to Topic 12.)
11. If unit is equipped with a power take-off clutch, check adjustment of the clutch operating lever. (Refer to Topic 22.)
12. Bar the engine over by hand to make certain it turns freely.
13. Check engine intake and exhaust systems to make certain they are unobstructed by foreign material. The exhaust line should not be restricted by sharp bends/crimps but should be kept as short as possible and installed with a minimum number of elbows. Total restriction of a naturally aspirated engine exhaust system must not exceed three inches mercury back pressure at the exhaust outlet under full load, full speed conditions. Total restriction of a turbocharged engine exhaust system must not exceed one inch mercury back pressure at the turbocharger outlet under full load, full speed conditions. (Refer to Topic 16.)

> CAUTION: All muffler and exhaust pipe extensions must be adequately supported and flexibly connected to avoid excessive strain on either the exhaust manifold or the turbocharger outlet.

B. SAFETY PRECAUTIONS

1. When operating the engine in a closed area, pipe exhaust fumes outside. Continued breathing of exhaust fumes may be fatal.
2. When servicing batteries, do not smoke or use an open flame in the vicinity. Batteries generate explosive gas during charging. Make sure there is adequate ventilation when charging batteries.
3. When filling fuel tank, do not smoke or use an open flame in the vicinity.
4. Be extremely careful when using a carbon tetrachloride fire extinguisher in a closed area as it produces toxic vapor. Provide adequate ventilation before entering a closed area where carbon tetrachloride has been used.

TOPIC 4. OPERATING CONTROLS AND INSTRUMENTS

Various controls and instruments are available to assist the operator in getting optimum service from the engine. Regardless of panel configuration or location, the operator must be familiar with the function of engine controls and instruments provided for operating the unit.

A. OPERATING CONTROLS

1. Engine Key Switch (Stop Control)

The engine key switch energizes the governor fuel solenoid circuit.

2. Starter Button

The starter button energizes the electric starting motor.

3. Throttle Control

The turn-to-lock type throttle control actuates the governor speed control lever. Engine speed is varied by pulling out on the throttle handle. The throttle is locked in position by turning the handle either clockwise or counterclockwise, and is released by returning it to mid-position.

4. Clutch Operating Lever

The clutch operating lever actuates the clutch mechanism to connect and disconnect engine load.

Figure 1. Not applicable.

5. Air Heater Switch

The air heater switch energizes the air heater element.

6. Magnetic Switch Reset Button

The magnetic switch reset button is pressed to complete circuit to the electric solenoid of the fuel injection pump before engine can be started after safety shut-down.

NOTE: Magnetic switch will not reset until button on oil pressure safety switch-gauge is reset.

B. INSTRUMENTS

1. Oil Pressure Gauge

The oil pressure gauge indicates pressure at which lubricating oil is circulating through the engine.

2. Ammeter

The ammeter indicates charging output of the alternator.

3. Water Temperature Gauge

The engine water temperature gauge indicates temperature of coolant being circulated in the cooling system.

4. Tachometer

The tachometer indicates engine speed in revolutions per minute (rpm).

5. Hourmeter

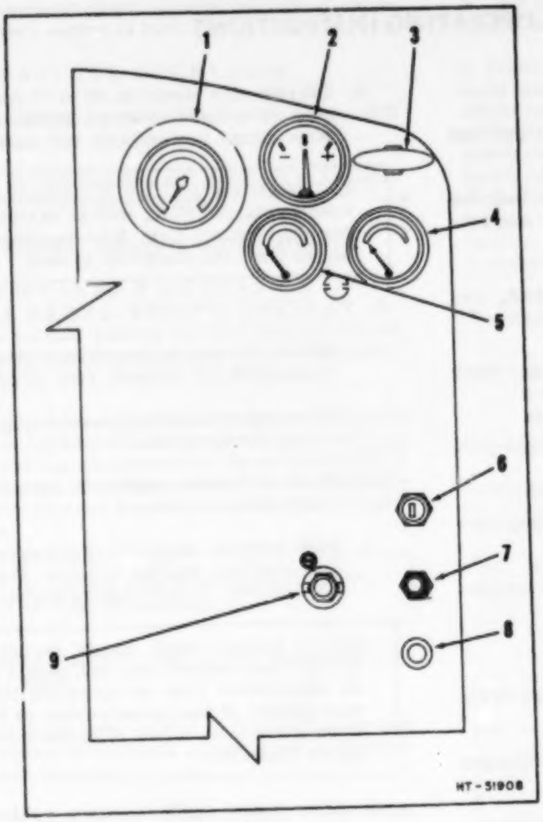
The hourmeter registers elapsed hours of engine operation.

6. Combination Tachometer and Hourmeter (Mechanical Type)

This combination is made available primarily for 1800 RPM engine operation. If the engine is operating at other than 1800 RPM, refer to the table below.

For actual hours run, divide hours on meter by figure opposite governed RPM.

GOVERNED RPM	DIVISOR
1500	.8333
1600	.8888
1800	1.0000
2000	1.1111
2200	1.2222
2400	1.3333



1. Tachometer
2. Ammeter
3. Throttle Control
4. Oil Pressure Gauge
5. Water Temperature Gauge
6. Key Switch
7. Starter Button
8. Air Heater Switch
9. Magnetic Switch Reset Button

Figure 2. Operating Controls and Instruments - Rear Panel Mounted

Figure 3. Not applicable.

TOPIC 5. OPERATING INSTRUCTIONS

A. OPERATING PRECAUTIONS

1. Always allow engine to warm up at reduced speed.
2. Keep engine and accessories clean. Check for loose connections, capscrews, bolts, and nuts while cleaning.
3. If engine overheats due to lack of coolant, replenish slowly while engine is running.
4. Do not run engine continuously at governed speed without load.
5. Do not allow engine to idle for prolonged periods except in sub-zero weather.
6. Refuel at end of days operation to keep condensation to a minimum.
7. Check all electrical wiring for loose connections. Keep battery clean.

B. STARTING ENGINE

1. Before starting a new engine, prepare it for operation as detailed in Topic 3.
2. Make certain engine clutch is in disengaged (neutral) position.
3. Place throttle control in FULL LOAD position.
4. Turn key switch to ON position.

NOTE: If engine is equipped with safety controls, refer to Topic 20 for starting procedure.

5. Press and hold air heater switch for 45 seconds minimum.
6. Press and hold starter switch while still holding air heater switch in the ON position. When engine starts, release both switches. If engine does not run on all cylinders immediately after starting, again press air heater switch for a short period until engine is running on all cylinders.

CAUTION: Do not use starting motor continuously for more than 30 seconds without a pause of two minutes to allow it to cool.

7. With engine running, move throttle control slowly to a fast idle position. Allow engine to warm up at this speed before applying load.
8. Oil pressure should be 30 to 55 psi at full load rpm. If pressure is not within these limits, stop engine immediately and correct trouble.

CAUTION: Do not use a commercial cold weather starting fluid, such as an ether starting aid, without first disconnecting the air heater from the electrical system.

C. PLACING ENGINE UNDER LOAD

1. Before starting engine, refer to Topic 3, PREPARATION OF ENGINE FOR OPERATION.
2. Start engine following procedure given in preceding Paragraph B.
3. Position throttle control to operate engine at 1/4 throttle or slower.
4. Push forward slowly on clutch operating lever until load has started to move, then push forward quickly to fully engage clutch.

NOTE: Engine clutch should engage with a definite over-center snap and should require an appreciable push on operating lever for engagement. If snap is not evident or if clutch slips under load, adjust it immediately. Refer to Topic 22.

5. After engine clutch engages, set throttle control and lock in position.

D. DURING OPERATION CHECKS

1. Observe general condition of engine while it is running.
2. Look for loose bolts, leaks, overheated assemblies, and listen for unusual noise.
3. Stop engine and make necessary repairs and adjustments.

E. STOPPING ENGINE

1. Move throttle control slowly to low idle speed.
2. Disengage engine clutch by pulling back clutch operating lever.

CAUTION: After disengaging clutch, allow engine to run at fast idle speed for at least 5 minutes to cool engine gradually and uniformly.

3. Stop engine by turning off key switch.

4. Cover exhaust pipe to prevent entrance of moisture when engine is idle.

F. HOT WEATHER OPERATION

1. Keep cooling system filled with clean, soft water.
2. Make certain that fins and passages of radiator are free of foreign material.
3. Keep external surface of engine clean.

G. COLD WEATHER OPERATION

1. Make certain battery is fully charged and all other electrical equipment is in first class condition.
2. Use glycol base anti-freeze solution to protect engine against damage by freezing. Refer to instructions on protection charts furnished by anti-freeze manufacturer for quantity of anti-freeze required for lowest anticipated temperature.

CAUTION: Do not use anti-freeze solutions that are harmful to aluminum.

3. Refer to Topic 17, for proper maintenance of air cleaner.
4. Provide radiator cover if thermostat proves inadequate to maintain normal coolant operating temperature.
5. At end of days operation, drain water from fuel tank and from the fuel sediment bowl.
6. When ambient temperature is minus 20°F or lower, a means of warming the engine and battery is recommended in order to obtain satisfactory starting and to prevent engine damage. It is suggested that crankcase oil be drained at end of days operation. When starting operations in minus 20°F temperatures and lower, heat oil to approximately 200°F and replace in oil pan.
7. If engine is equipped with optional cold weather starting aid, refer to Topic 21.

CAUTION: Remove air heater cable between air heater solenoid switch and starter solenoid or disconnect this cable at starter solenoid end and tape end of cable. Engine damage will result if ether starting fluid is accidentally ignited by the air heater element.

8. If engine is to be operated in arctic temperatures, consult your nearest authorized dealer for information regarding availability of special cold weather equipment.

H. EXERCISE OF ENGINE ON STANDBY SERVICE

A diesel engine on standby service that is customarily operated under optimum conditions, should be exercised at least every 30 days. However, under environmental conditions involving extreme temperatures, humidity, dust, sand, etc., it may be found necessary to shorten the interval between exercise periods to as often as weekly. Exercise period should be long enough to enable the engine to attain normal operating temperature while carrying, if possible, at least 50% of its normal load.

To exercise engine, proceed as follows:

1. Before starting engine, check lubricating oil and coolant levels. Make complete visual inspection of unit to be sure it is in operating condition.
2. Start engine and run 15 minutes at one-half throttle.
3. Run engine at full throttle with whatever load is available, up to full load, for the period of time required to obtain two consecutive water temperature readings of 160°F minimum, taken at a 15 minute interval. Then continue to operate engine for 30 minutes. Check and correct any coolant or oil leaks.

NOTE: If no load, or a very light load, must be used during exercise period, cover the radiator, if engine is so equipped, to hasten the warm-up period.

CAUTION: Do not cover radiator of an unattended engine.

4. Run engine at one-half throttle with no-load for 5 minutes to allow combustion chamber temperatures to decrease gradually to a minimum.
5. Stop engine.

NOTE: If the accumulated hours of operation during the above exercise periods do not total 100 hours (recommended lube filters and lubricating oil change period) during a six month period, it is recommended that the filters and lubricating oil be changed at a maximum of every six months. If the accumulated hours of operation during the above exercise periods do not total 500 hours (recommended fuel filter change period) during a 12 month period, it is recommended that the fuel filter element be replaced at the end of the 12 month period.

TOPIC 6. LUBRICATION RECOMMENDATIONS

A. ENGINE LUBRICATING OIL

As a general recommendation, Service DS, Series 3, lubricating oil applies to all turbocharged engines in any application. It will also apply to naturally aspirated engines in severe operation applications, or when fuel sulphur content exceeds 0.5%. For most normal duty applications of naturally aspirated engines, Service DM lubricating oil will apply.

Recommended SAE weights of oils to be used in "Allis-Chalmers" engines are:

Ambient Temperature	SAE
0°F and below	10W
0°F to 32°F	20
Above 32°F	30

Our specification of 100 hours for filter and oil change periods is based on the use of high quality oils, fuels with less than .5% sulphur, and average engine loads not exceeding the continuous rating with engines in good adjustment and operating with coolant and lubricating oil temperatures between 170° and 200°. Variations from these considered normal operating conditions must be compensated for by more frequent oil change and/or filter change periods. Our recommendations for oil change periods are further based on what experience has shown to be conservative and safe hours of operation between oil changes.

The quality of the oils and additive compounds used, and the additive quantity in various brands of lubricating oils affects their performance level. Under severe operating conditions, with engines in poor mechanical condition, or when using high sulphur fuels, lubricating oils will deteriorate at a faster rate. For these reasons oil change periods can vary.

After 100 hours of operation, actual tests of the lubricating oil at intervals of 10 to 20 hours to determine oil condition, may either allow extending or necessitate shortening of oil/oil filter change periods. This testing service is provided by most major oil companies. We recommend that our customers take advantage of this service.

Most manufacturers of lubricants recognize the importance of the quality required for use in Allis-Chalmers engines and are cooperating fully to assure the use of only those oils which fulfill these requirements. The oil distributor and oil manufacturer are to be held responsible for the results obtained from their products. Acquire your lubricants from manufacturers and suppliers with unquestioned integrity, supplying known and tested products. Do not jeopardize your engine with inferior lubricating oils.

Optimum oil life and also optimum engine life can be realized if the following items are given proper consideration.

1. Use of quality fuels meeting our published specifications.
2. Adequate turbocharger and combustion chamber cooling by running engine at a fast idle for 5 minutes before shutdown.
3. Proper attention to air cleaner service and prevention of leaks in the air intake system.
4. Engine Adjustment:
    a. Correct fuel settings.
    b. Fuel injection pump timing.
    c. Injection nozzle function and opening pressure.
    d. Valve clearance settings.
5. Cleanliness with lubricating oil, oil containers, oil storage facilities, and oil fill caps and pipes on engines. "Properly maintain lube oil filters."
6. Proper attention to entire cooling system including removal of antifreeze and flushing system for summer operation, maintaining specified operating temperature, maintaining fan belts and water pump drive belts in correct adjustment, and keeping radiator surfaces free of debris.

B. GREASE

1. Pressure Gun Lubricant

    Use a ball and roller bearing lubricant that has a minimum melting point of 300°F. It must be waterproof and have a viscosity that assures easy handling in the pressure gun at prevailing ambient temperatures.

TOPIC 7. FUEL OIL RECOMMENDATIONS

A. GENERAL

Diesel fuel must be a petroleum oil product and must have certain qualities in order to ignite and burn at the proper rate and temperature (Paragraph B).

The following rules cover handling of diesel fuel before it reaches the fuel injection pump:

1. Do not handle fuel in an open container where there is dust and dirt blowing around.
2. Do not use "waste" or linty rags around fuel containers or fuel injection pumps.
3. Clean all storage tanks at regular intervals.
4. If hand pumps are used to bring fuel oil from storage tanks, keep them covered with dust-proof covers when not in use.
5. When drawing fuel oil from a drum, agitate drum as little as possible and leave from two to three inches of fuel in bottom of drum.
6. Keep fuel handling equipment clean at all times and covered when not in use.
7. Use funnel equipped with a 200-mesh wire screen.

B. FUEL OIL SPECIFICATIONS

Field experience has shown that the fuel best suited for these engines closely approximates the following specifications:

Gravity API	30-35
Viscosity Saybolt Universal at 100°F	35-40
Flash Point	150°F
Diesel Index	48.5-65.5
Cetane Number	46-60
Pour Point	0°F
Volatility 90%	650°F max
End Point 98%	
Summer	700°F max
Winter	600°F preferable
Sediment and Water	Trace
Ash	.02 of 1% max
Conradson Carbon	.03 of 1% max
Sulphur	1/2 of 1% max

Generally, a No. 2 diesel fuel purchased from a reputable oil company will meet the above specifications. (Distillates should be used only in emergencies. When proper fuel is again available, drain fuel system before adding proper fuel.)

> CAUTION: Sulphur content of diesel fuel should not exceed 1/2 of 1%.

C. FUEL OIL STORAGE

The importance of proper fuel oil storage cannot be over-emphasized. Storage tanks, drums, or service tanks must be free of rust, scale, sediment, or any other foreign matter which will contaminate fuel. Contaminated fuel will clog engine fuel filter and eventually damage fuel injection pump and fuel injection nozzles.

TOPIC 8. LUBRICATION AND SERVICE SCHEDULE, AND MAINTENANCE TOOLS

A. GENERAL

Preventive maintenance includes such normal servicings that will keep the engine in peak operating condition and prevent unnecessary trouble from developing. These servicings are periodic lubrication and inspection of the moving parts and accessories of the engine.

Lubrication is an essential part of protective maintenance, controlling to a great extent the useful life of the unit. Different lubricants are needed and some components in the unit require more frequent lubrication than others. Therefore, it is important that the instructions regarding types of lubricants and frequency of their application be closely followed.

To prevent minor irregularities from developing into serious conditions that might involve shutdown and major repair, several other services or inspections are recommended for the same intervals as the periodic lubrication. The purpose of these services, or inspections, is to assure the uninterrupted operation of the unit.

> NOTE: The varied applications to which the engines are subjected in actual service can considerably lengthen or shorten the hours of operation the engines will satisfactorily run between major overhauls, piston ring replacements, and valve reconditionings. Observation of crankcase breathing, exhaust sound and color, lubricating oil consumption, engine power, and the sound of the engine in operation by a qualified diesel mechanic will determine the need for reconditioning.

Thoroughly clean all lubrication fittings, caps, filler and level plugs and their surrounding surfaces before servicing. Prevent dirt from entering with lubricants and coolants. The intervals given in the schedule are based on normal operation; perform these services, inspections, etc., more often (as needed) for operation under abnormal or severe conditions.

For detailed information regarding lubrication, inspection, or service procedures for any given components, refer to topic in the manual pertaining to the part, assembly, or system.

B. LUBRICATION AND SERVICE GUIDE

Recommended lubrication and service intervals are given in the following schedule:

LUBRICATION AND SERVICE SCHEDULE

	Reference								
	Topic	Paragraph	Daily	Each 100 Hours	Each 500 Hours	Each 1000 Hours	Each 2000 Hours	Each 3000 Hours	Each 6000 Hours
Visually inspect-engine and accessories for loose connections, nuts, bolts, and capscrews, leaking seals, gaskets, fuel lines and air connections.	5	D	X						
Check radiator coolant level. Fill to within 1-1/2" of filler neck.	11	D	X						
Drain water from fuel tank and check fuel supply.	5	G	X						
Drain water from fuel sediment bowl.	12	B	X						
Air cleaner (Donaldson oil bath) - Inspect oil cups and service when 1/2" dirt has collected.	17	B	X						
Check oil level in oil pan at start of day's operation. Bring level up to the high mark on the oil level gauge (dipstick).	13	B	X						
Grease power take-off clutch throwout collar.	22	B	X						

LUBRICATION AND SERVICE SCHEDULE (CONTINUED)

	Reference		Daily	Each 100 Hours	Each 500 Hours	Each 1000 Hours	Each 2000 Hours	Each 3000 Hours	Each 6000 Hours
	Topic	Para-graph							
Air cleaner (Donaldson dry type) - Inspect daily or more often if necessary. Refer to text.	17	B	X						
Drain water from air compressor reservoir.	18	B	X						
Make certain the radiator core is free of obstructions.	11	E	X						
Using engine oil, lubricate the throttle control linkage.	4	A		X					
Check condition and tension of alternator and water pump drive belts.	11	H		X					
Change engine lubricating oil.	13	D		X					
Renew engine lubricating oil filters.	13	D		X					
Service Air Maze air cleaner.	17	B		X					
Inspect Turbocharger.	19	D		X					
Check liquid level of the battery cells.	14	C		X					
Power take-off clutch - Grease the shaft bearings, pilot bearing and operating lever shaft.	22	B		X					
Check clutch for proper adjustment.	22	C		X					
Check compressor drive belt and mounting bolts.	18	B		X					
Inspect alternator and regulator.	14	E-F			X				
Check timing of fuel injection pump to engine.	12	D			X				
Engine breather tube - Remove, wash in solvent, and dry with compressed air.	13	E			X				
Renew combination primary and secondary fuel filter.	12	B			X				
Check valve lash adjustment.	15	A			X				
Inspect starter.	14	D			X				
Check specific gravity of each battery cell. Inspect and clean battery cables.	14	C			X				
Clean or replace filters in air compressor governor.	18	B			X				
Service air compressor.	18	B				X			
Clean exterior of engine.	5	A					X		

LUBRICATION AND SERVICE SCHEDULE (CONTINUED)

	Reference		Daily	Each 100 Hours	Each 500 Hours	Each 1000 Hours	Each 2000 Hours	Each 3000 Hours	Each 6000 Hours
	Topic	Para-graph							
Air cleaner (Donaldson oil bath). Remove and clean body assembly.	17	B					X		
Inspect Turbocharger.	19	E					X		
Check spray pattern and opening pressure of fuel injection nozzles.	12	F					X		
Inspect and clean spray nozzle orifice in cold weather starting aid.	21	D					X		
Clean oil pan and oil pump suction screen.	13	E						X	
Clean oil pump pressure relief valve.	13	E						X	
Clean oil pressure regulating valve.	13	E						X	
* Main and connecting rod bearings - Check for condition and excessive wear.								X	
* Intake and exhaust valves - Remove carbon and grind valves.								X	
* Piston rings - Replace piston rings.								X	
* Disassemble engine and all accessories. Make major inspection of all components. Replace or repair parts as required.									X

* See NOTE in Paragraph A of this Topic.

C. MAINTENANCE TOOLS

The following tool listing has been prepared to assist service and maintenance personnel in the selection of tools (other than standard hand or shop tools) to accomplish the various maintenance operations described and illustrated in this manual. These tools must be ordered directly from the Kent-Moore Organization, Inc., Service Tool Division Order Dept., 1501 South Jackson Street, Jackson, Michigan.

TOPIC	FIGURE	DESCRIPTION	KENT-MOORE TOOL NUMBER
9	2	Compression Gauge Assembly	J-6692
9	2	Compression Gauge Adaptor (Less Tip)	J-22472
9	2	Compression Gauge Adaptor Tip	J-21616
12	11	Nozzle Remover Adaptor	J-8689
12	11	Slide Hammer	J-6471-1
12	12	Nozzle Tester Set	J-8625
12	12	Spray Collector	J-6445-50
		Carrying Case for J-8625	J-6445-34
12	13	Injection Nozzle Holding Fixture	J-6999
12	15	Pin Vise	J-4298-1
12	15	Nozzle Hole Cleaning Wire (3400)	J-8537-2
12	15	Nozzle Hole Cleaning Wire (3500)	J-8537-3
12	16	Injection Nozzle Bore Cleaner	J-21609-7
15	2	Feeler Gauge Set	J-3172

TOPIC 9. TROUBLESHOOTING

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D. FUEL SYSTEM 6
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A. GENERAL

It has been proved that over 90% of the troubles that occur in engine operation are avoided when those responsible for maintenance adhere to an adequate program of lubrication, inspection, and maintenance. The time and expense involved in such programs is only a fraction of that incurred when poor maintenance practice results in a major malfunction or breakdown.

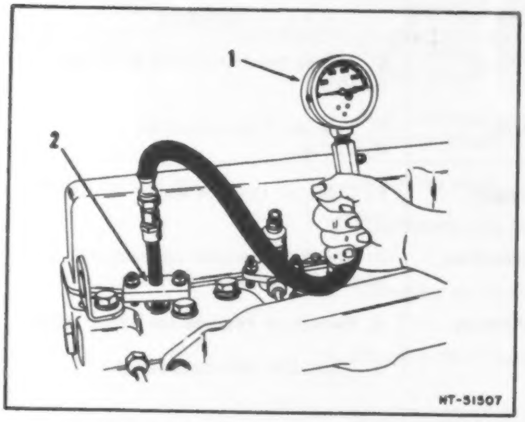
In most cases, when a trouble is detected and remedied immediately, a more expensive, time-consuming repair will be avoided. The following list of symptoms, causes, and remedies is given to aid the operator in locating and correcting mechanical and electrical troubles as quickly as possible. For detailed inspection and service procedures for any given component, refer to that section or topic in the manual pertaining to the part, assembly, or system.

B. ENGINE

TROUBLE	POSSIBLE CAUSES	REMEDY
Engine will not turn	1. Batteries weak.	1. Recharge or replace batteries.
	2. Starter or starter switch inoperative.	2. Repair or replace defective parts.
	3. Engine locked or seized.	3. This can be due to extended idle or storage periods, or to improper preparation of the engine for storage, in which case the parts may be rusted or corroded and seized. Broken piston rings, gears, etc., may also cause locking. Repair or replace defective parts.
	4. Hydro-static lock.	4. This can be due to rain water entering uncovered exhaust pipe, leaking cylinder head gasket, cracked block or cylinder head. Repair or replace defective parts.
Engine will not start	1. Slow cranking speed.	1. Specific gravity of batteries too low. Charge batteries. Starter not delivering maximum torque. Repair or replace defective parts. Use cold weather starting aids if applicable.
	2. Engine controls out of adjustment.	2. Check all engine control linkages for proper adjustment.
	3. Insufficient supply of fuel to fuel injection nozzles.	3. Check fuel system and clean sediment bowl.

TROUBLE	POSSIBLE CAUSES	REMEDY
Engine will not start (Cont)	4. Fuel injection nozzles not operating properly.	4. Test and repair or replace nozzles.
	5. Fuel injection pump improperly timed.	5. Time fuel injection pump.
Engine hard to start	1. Batteries weak.	1. Recharge or replace batteries.
	2. Insufficient fuel in fuel tank.	2. Check fuel level in tank. Fill with specified fuel if necessary.
	3. Incorrect grade of fuel.	3. Drain fuel system. Fill the tank with the specified fuel.
	4. Clogged filter/sediment bowl.	4. Replace filter, clean sediment bowl.
	5. Fuel injection nozzles not operating properly.	5. Test and repair or replace nozzles.
	6. Fuel transfer pump not operating properly.	6. Test and repair or replace fuel transfer pump.
	7. Air in fuel system.	7. Correct air leaks in suction side of fuel system. Vent fuel system.
	8. Insufficient air supply to cylinders.	8. Clean air system.
	9. Fuel injection pump improperly timed.	9. Time fuel injection pump.
	10. Valve lash incorrect.	10. Adjust valve lash.
	11. Piston rings or cylinder liners worn.	11. Replace affected parts.
	12. Valves warped or pitted.	12. Recondition or replace valves and/or valve guides.
Engine stops frequently	1. Idling speed too low.	1. Adjust low idling speed.
	2. Restricted fuel supply.	2. Check fuel system.
Engine stops suddenly	1. Out of fuel.	1. Fill fuel tank with specified fuel and vent the fuel system.
	2. Restricted fuel supply.	2. Check fuel system.
	3. Broken or loose fuel lines.	3. Correct or replace affected parts.
	4. Fuel transfer pump or fuel injection pump inoperative.	4. Replace inoperative parts.
Engine overheats	1. Leak in cooling system.	1. Correct all leaks and fill cooling system.
	2. Radiator core clogged.	2. Clean and flush radiator.
	3. Radiator air passages clogged.	3. Remove debris from radiator core.

TROUBLE	POSSIBLE CAUSES	REMEDY
Engine overheats (Cont)	4. Fan drive belts too loose.	4. Adjust fan drive belts to proper tension.
	5. Thermostat inoperative.	5. Test the thermostat for proper operation.
	6. Engine oil cooler clogged.	6. Clean or replace the oil cooler core.
	7. Improper engine lubrication.	7. Check for proper operation of engine lubricating oil pump.
	8. Water pump malfunctioning.	8. Repair or replace the water pump.
	9. Fuel injection pump improperly timed.	9. Time fuel injection pump.
Engine shows loss of power	1. Insufficient supply of air to cylinders.	1. Clean air system.
	2. Insufficient supply of fuel to fuel injection nozzles.	2. Check fuel system.
	3. Governor not operating properly.	3. Inspect and adjust governor
	4. Air in fuel system.	4. Vent fuel system. Check for air leaks on suction side of fuel transfer pump.
	5. Clogged fuel filter.	5. Change filter element.
	6. Improper valve lash.	6. Adjust valve lash.
	7. Fuel injection pump improperly timed.	7. Time fuel injection pump.
	8. Inoperative fuel injection pump or fuel injection nozzles.	8. Repair or replace affected parts.
	9. Cylinder cutting out.	9. Locate "missing" cylinder as follows: Run engine at low idle speed and cut out each fuel injection nozzle in turn by loosening the fuel injection line nut attaching line to fuel injection pump. A decrease in engine speed with line nut loosened indicates nozzle for that cylinder is functioning properly. If engine speed does not decrease, nozzle is malfunctioning and must be replaced.
	10. Loss of compression.	10. This may be due to leaking valves or to worn piston rings or cylinder sleeves. Use a suitable compression tester, Figure 2, and check each cylinder as detailed in following paragraphs.



1. Compression Tester Gauge Assembly
2. Compression Tester Adaptor

Figure 1. Checking Compression Pressure

Compression pressure for a normal engine at normal operating temperature firing on five cylinders at 600 rpm and at sea level conditions is 500 psi.

When checking compression pressure, altitude at which engine is located must be taken into consideration for an accurate evaluation of test, because the density of air decreases as altitude increases. For each 1000 feet of altitude above sea level the specified sea level figure of 500 psi must be derated 3%.

It is common practice to consider a differential of 25 psi between one or more cylinders as an indication of possible trouble. This is not always true. Pressure readings taken at 600 rpm are not always representative of what is happening within the engine at 1800 or 2000 rpm, under load. If a spread between cylinders of 25 psi or more at 600 rpm is noted and there is no evidence of excessive oil consumption, intake or exhaust valve blow-by into the manifolds, or loss of engine power, it is safe to continue to operate the engine. However, if any of the above conditions exist, or if a difference of 50 psi or more is noted between cylinders, the cylinder head should be removed and a detailed inspection made of cylinder head, valves, pistons, rings, and cylinder sleeves, and necessary repairs should be made to eliminate cause of the low compression pressure.

NOTE: In order to obtain an accurate pressure indication, make certain the compression tester gauge has been properly tested and calibrated. Do not rebuild an engine because of low compression readings obtained with a compression tester unless the gauge is known to be accurate.

To check compression pressure, proceed as follows:

a. Start engine and warm up to a minimum temperature of 160°F.

b. Shut off engine. Remove drip manifold from the nozzle holder assemblies. Either plug or connect a rubber hose to the upper end of the tube assembly that connects the drip manifold to the overflow tee at the injection pump. If hose is used, place lower end of hose in a container in order to collect fuel overflow from the injection pump.

CAUTION: Do not plug return of fuel to tank.

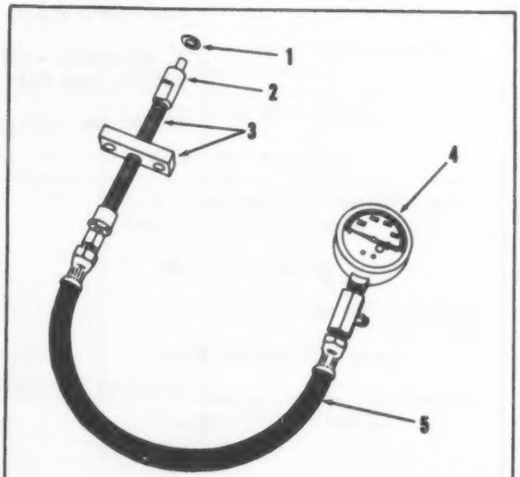
c. Start compression check on cylinder Number 1. Remove the fuel injection nozzle and install compression tester adapter and washer in same manner the fuel injection nozzle was installed. Install the compression tester hose and gauge assembly. (See Figure 1.)

d. Start engine and run at approximately 600 rpm. Take several readings on gauge.

NOTE: Do not check compression by cranking engine with starter.

e. Stop engine and remove the compression tester assembly. Install nozzle-holder assembly. Connect fuel injection line.

f. Repeat procedure detailed above in Steps c, d, and e, to check compression of each of the remaining cylinders.



1. Nozzle Gasket
2. Adaptor Tip
3. Adaptor
4. Compression Gauge
5. Hose Assembly

Figure 2. Tools for Checking Compression

TROUBLE	POSSIBLE CAUSES	REMEDY
Engine runs unevenly and vibrates excessively	1. Governor not operating properly.	1. Adjust governor and linkage.
	2. Fuel supply erratic or insufficient.	2. Check fuel system.
	3. Engine operating temperature too low.	3. Check thermostats.
	4. Fuel injection pump malfunctions.	4. Check fuel injection pump.
	5. Valves in bad condition.	5. Recondition valves.
	6. Cylinder "cutting-out."	6. Correct cause.
	7. Fuel injection nozzle malfunctions.	7. Repair nozzle.
Engine emits black smoke from exhaust	1. Air system clogged.	1. Check engine air intake system.
	2. Fuel injection pump roller-to-roller dimension incorrect.	2. Correct roller-to-roller dimension.
	3. Improper fuel.	3. Drain fuel system and refill with specified fuel.
	4. Lack of good fuel injection nozzle spray pattern.	4. Clean and adjust nozzles.
Engine emits bluish-white smoke from exhaust	1. Engine operating temperature too low.	1. Check thermostat.
	2. Clogged fuel injection nozzles.	2. Clean and adjust nozzles.
	3. Low compression.	3. Make compression test and necessary repairs.
	4. Early fuel injection pump timing.	4. Test and adjust.
Engine detonates or knocks	1. Fuel pump improperly timed.	1. Check and adjust.
	2. Loose bearings.	2. Replace bearings.
	3. Loose piston.	3. Inspect piston assembly. Replace parts required.
	4. Loose flywheel.	4. Check tightness of flywheel bolts and dowel. Tighten/replace parts required.
	5. Improperly adjusted valve(s).	5. Check and adjust.
	6. Foreign material in cylinder(s).	6. Make necessary repairs.

C. STARTING SYSTEM

TROUBLE	POSSIBLE CAUSES	REMEDY
Starter will not crank engine	1. Batteries weak.	1. Check batteries.
	2. Cables and/or connections loose or corroded.	2. Tighten all loose connections and clean corrosion from all terminals.
	3. Starter switch inoperative.	3. Replace switch.
	4. Starter brushes worn or not contacting properly.	4. Install new brushes or fit brushes to conform to contour of commutator.
	5. Starter brush springs weak.	5. Check brush spring tension, replace springs if necessary.
	6. Starter commutator dirty or worn.	6. Polish commutator, machine commutator and under-cut mica if necessary.
	7. Starter armature shaft brushings worn (armature drags on fields).	7. Replace worn bushings and related items.
	8. Starter armature burned out.	8. Replace armature.
Starter pinion will not engage with flywheel ring gear	1. Grease and/or dirt in starter drive mechanism.	1. Disassemble and clean the drive assembly.
	2. Broken or excessively worn parts.	2. Replace broken or worn parts.

D. FUEL SYSTEM

TROUBLE	POSSIBLE CAUSES	REMEDY
Insufficient fuel supply to fuel injection nozzles	1. No fuel in fuel tank.	1. Fill fuel tank with specified fuel. Vent fuel system.
	2. Inoperative fuel transfer pump.	2. Repair or replace transfer pump.
	3. Fuel injection nozzle valve binding in valve body.	3. Replace valve assembly in nozzle holder body.
	4. Fuel lines/fuel filter/sediment bowl clogged.	4. Clean fuel system components, replace fuel filter.
	5. Fuel injection pump malfunctioning.	5. Replace fuel injection pump.
	6. Fuel injection nozzles improperly adjusted.	6. Adjust fuel injection nozzles.
Air in fuel system	1. Loose fuel line fitting or leak in fuel line on suction side of fuel transfer pump.	1. Tighten loose fitting or replace damaged line.
	2. Damaged gasket on first stage fuel filter.	2. Replace gasket.

E. AIR INTAKE SYSTEM

TROUBLE	POSSIBLE CAUSES	REMEDY
Insufficient air supply to cylinders	1. Air cleaner clogged.	1. Replace air filter element.
	2. Foreign material lodged in turbocharger impeller or turbine.	2. Disassemble and clean.
	3. Excessive dirt buildup in compressor or turbocharger.	3. Thoroughly clean compressor assembly.
	4. Excessive dirt buildup in compressor in short period of time.	4. Clean compressor assembly, and service air intake system for leaks.
	5. Leaks in engine intake and/or exhaust manifolds reducing turbocharger efficiency.	5. Tighten loose manifold retaining nuts or capscrews. Replace manifold gaskets.
	6. Turbocharger rotating assembly bearing seized.	6. Overhaul turbocharger.
Rapid wear on engine parts	1. Dirt admitted with intake air.	1. Inspect air cleaner body, pipe, connecting hoses, gaskets, etc., thoroughly for cracks or openings which would allow air to enter engine without passing through air cleaner. Make necessary repairs.
	2. Dirty lubricating oil.	2. Change engine oil and the lubricating oil filter elements at the intervals recommended. Keep oil clean when filling engine.
	3. Improper fuel.	3. Use the proper fuel. It is important that the fuel be within the specified limits for ash, carbon, sulphur, etc., to prevent excessive wear on engine parts.

F. COOLING SYSTEM

TROUBLE	POSSIBLE CAUSES	REMEDY
Engine operating temperature too high with ample coolant in system	1. Temperature gauge inoperative.	1. Check gauge. Replace if necessary.
	2. Radiator air passages restricted.	2. Clean exterior of radiator.
	3. Thermostat inoperative.	3. Replace thermostat.
	4. Loose or broken fan drive belts.	4. Adjust or replace fan drive belts.
	5. Lime deposits in water passages of radiator, cylinder heads and/or cylinder block.	5. Thoroughly clean affected parts.
	6. Water passages in oil cooler restricted.	6. Remove and clean oil cooler core.

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TROUBLE	POSSIBLE CAUSES	REMEDY
Engine operating temperature too high with ample coolant in system (Cont)	7. Water pump inoperative.	7. Repair or replace water pump.
	8. Engine pulling excessive load.	8. Reduce load.
	9. Engine speed set too high.	9. Adjust speed to within specified rpm limits.
Engine operating temperature too high due to loss of coolant	1. External leaks.	1. Repair affected parts.
	2. Ruptured oil cooler core (oil in coolant).	2. Replace oil cooler core.
	3. Engine or air compressor cylinder head gaskets leaking.	3. Replace gaskets and torque cylinder head nuts as specified.
	4. Engine or air compressor cylinder heads cracked.	4. Replace cylinder head.
	5. Engine or air compressor cylinder block cracked.	5. Replace cylinder block.
Engine operating temperature too low	1. Thermostat stuck in open position.	1. Replace thermostat.
	2. Operating in extremely cold weather.	2. Provide covers for radiator and engine side openings.

G. LUBRICATING SYSTEM

TROUBLE	POSSIBLE CAUSES	REMEDY
No lubricating oil pressure	1. Insufficient oil in crankcase.	1. Fill crankcase to proper level.
	2. Oil pressure gauge inoperative.	2. Replace gauge.
	3. Lubricating oil pump screen clogged.	3. Remove and clean the screen.
	4. Lubricating oil pump inoperative.	4. Repair or replace oil pump.
	5. Oil line loose or broken inside crankcase.	5. Repair or replace affected parts.
Low lubricating oil pressure with proper oil level in crankcase	1. Oil pressure gauge inaccurate.	1. Check gauge. Replace if necessary.
	2. Oil pressure relief valve or regulator valve stuck in open position.	2. Clean, repair, or replace affected parts.
	3. Oil line in crankcase loose or broken.	3. Repair or replace affected items.
	4. Improper lubricant.	4. Fill crankcase with specified lubricant.
	5. Main and/or connecting rod bearings worn.	5. Replace bearings.

TROUBLE	POSSIBLE CAUSES	REMEDY
Low lubricating oil pressure with proper oil level in crankcase (Cont)	6. Camshaft bearings worn.	6. Replace bearings.
	7. Lubricating oil pump worn.	7. Repair or replace oil pump.
	8. Air compressor connecting rod bearings worn.	8. Replace bearings.
Excessive lubricating oil pressure	1. Oil pressure gauge inaccurate.	1. Check gauge. Replace if necessary.
	2. Oil pressure regulating valve improperly adjusted.	2. Adjust valve to obtain proper pressure.
	3. Improper lubricant.	3. Fill crankcase with specified lubricant.
Overheating of lubricating oil	1. Insufficient oil in crankcase.	1. Fill crankcase to proper level.
	2. Improper lubricant.	2. Fill crankcase with specified lubricant.
	3. Engine oil cooler clogged.	3. Clean or replace the oil cooler.
Excessive oil consumption	1. External oil leakage (gaskets, etc.).	1. Correct all external leaks.
	2. Engine or air compressor oil seals worn or damaged.	2. Replace oil seals.
	3. Lubricating oil too light.	3. Fill crankcase with specified lubricant.
	4. Pistons, rings, and/or cylinder sleeves worn.	4. Replace affected parts.
	5. Oil control rings stuck in piston ring grooves.	5. Clean ring grooves and replace rings.
	6. Valve guides worn.	6. Replace valve guides. Check related parts.
Excessive oil consumption during first 250 hours of operation and no indication of improvement	1. Rings not seated properly.	1. Allow more time for break-in. Make certain specified lube oil is used and engine is at operating temperature.
	2. Engine oil viscosity too light.	2. Use recommended viscosity.
Rapid wear on engine parts	1. Lubricating oil contaminated.	1. Fill system with clean engine oil. Replace engine oil filters.
	2. Improper engine lubricating oil being used.	2. Fill system with engine lubricating oil of proper specifications.

H. ELECTRICAL SYSTEM

TROUBLE	POSSIBLE CAUSES	REMEDY
Alternator not charging	1. Alternator drive belt loose or broken.	1. Adjust or replace drive belt.
	2. Alternator regulator inoperative.	2. Remove regulator for repair or replacement.
	3. Alternator inoperative.	3. Remove alternator for repairs or replacement.
Alternator output low and/or unsteady	1. Alternator drive belt improperly adjusted.	1. Adjust drive belt.
	2. Brushes sticking in brush holders.	2. Free brushes in holders.
	3. Brush spring tension too low.	3. Replace brush springs.
	4. Slip ring dirty or worn.	4. Clean slip ring or remove alternator for repair or replacement.
	5. Voltage regulator operating improperly.	5. Remove regulator for repair or replacement.
Batteries will not hold charge	1. Loose terminals or connections.	1. Tighten affected parts.
	2. Short in electrical system.	2. Correct short.
	3. Short circuit in battery.	3. Remove and repair or replace battery.
	4. Electrolyte level low (alternator output excessive or cracked battery case).	4. Reduce charging rate. Remove and repair or replace battery.
	5. Voltage regulator inoperative.	5. Remove regulator for repair or replacement.

I. INSTRUMENTS

If any of the instruments fail to register proper readings while the engine is in operation, the system to which the instrument applies should be thoroughly checked as outlined in the preceding parts of this Section to determine the cause. If failure of the instrument is suspected, test by installing a new, tested, instrument in its place. Replace any inoperative instruments.

TOPIC 10. FITS AND TOLERANCES; BOLT, CAPSCREW, AND NUT TORQUE WRENCH SPECIFICATIONS; STUD GAUGE HEIGHTS

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A. FITS AND TOLERANCES

DESCRIPT.	SIZE OF NEW PARTS
1. Cylinder Sleeves	
a. Type	Replaceable Wet
b. Inside diameter	4.2495" - 4.2510"
c. Diameter of sleeve at machined area just below flange	4.811" - 4.813"
d. Diameter of cylinder sleeve at packing ring location	4.749" - 4.751"
e. Sleeve flange outside diameter	4.998" - 5.002"
f. Cylinder block-to-sleeve clearance at sleeve lower diameter	.001" - .005"
g. Cylinder block-to-sleeve clearance at machined area just below flange	.0005" - .0045"
h. Cylinder block-to-sleeve clearance at sleeve flange	.004" - .013"
i. Clearance of piston skirt with sleeve	.0065" - .0090"
j. Fire wall height above cylinder sleeve flange	.0445" - .0475"
k. Top surface of cylinder sleeve flange above cylinder block with sleeve installed	.002" - .005"
l. Flange height adjusting shims available	.005", .010", .015" and .020"
m. Allowable taper	.0015"
n. Allowable out-of-round (when installed)	.0015"

DESCRIPTION	SIZE OF NEW PARTS
2. Cylinder Block	
a. Counterbore diameter in cylinder block for cylinder sleeve flange	5.006" - 5.011"
b. Depth of counterbore for cylinder sleeve flange	.3150" - .3165"
c. Bore in cylinder block for cylinder sleeve - Top	4.8135" - 4.8155"
d. Bore in cylinder block for cylinder sleeve - Bottom	4.752" - 4.754"
e. Bore in cylinder block for camshaft bearings	2.259" - 2.260"
f. Bearing bore in cylinder block for main bearings (without bearing, cap in place, and capscrews tightened to specified torque)	3.5607" - 3.5614"
3. Pistons	

NOTE: Combustion chamber is in piston.

a. Combustion chamber I.D.	2.998" - 3.002"
b. Combustion chamber depth	.592" - .596"
c. Material	Aluminum alloy
d. Length	5.824" - 5.829"
e. Diameter between top and second ring groove	4.218" - 4.222"
f. Diameter at bottom of skirt measured at right angle to piston pin	4.242" - 4.243"
g. Bore for piston pin	1.5014" - 1.5016"
h. Measurement from center of piston pin bore to top of piston	3.142" - 3.146"
i. Clearance of piston skirt with sleeve	.0065" - .0090"
4. Piston Pins	
a. Type	Full Floating
b. Piston pin length	3.601" - 3.616"
c. Diameter of pin	1.5015" - 1.5017"
d. Fit of pin in piston at room temperature	.0001" loose .0003" tight
e. Inside diameter of connecting rod bushing	1.5027" - 1.5032"
f. Piston pin to connecting rod bushing clearance	.001" - .0017"
5. Piston Rings	
a. Number of rings on each piston	4
b. Location of rings	3 compression rings and 1 oil control; all above piston pin
c. Gap between ends - fitted	
1. Model 3400	
1st ring (chrome compression)	.027" min - .047" max
2nd and 3rd ring (compression)	.015" min - .030" max
4th ring (oil segments)	.013" min - .058" max
2. Model 3500	
1st ring (chrome compression)	.019" min - .034" max
2nd and 3rd ring (compression)	.015" min - .030" max
4th ring (oil segments)	.013" min - .058" max
d. Clearance of rings in grooves	
1st ring (chrome compression)	.0065" - .0060"
2nd and 3rd ring (compression)	.0030" - .0050"
4th ring (oil segments)	.0025" - .0065"

NOTE: Only standard size rings are available.

6. Crankshaft	
a. Journal diameter for connecting rods	2.7475" - 2.7485"
b. Journal diameter for main bearings	3.247" - 3.248"
c. Width between connecting rod journal cheeks	1.562" - 1.565"

DESCRIPTION	SIZE OF NEW PARTS
d. Width of main bearing journals	
Front	2.147" - 2.167"
Intermediates	1.685" - 1.689"
Center	2.061" - 2.063"
Rear	2.014" - 2.017"
e. Crankshaft end clearance	.007" - .013"
f. Separate type thrust flanges	Available in standard size and .005", .010", .015" oversize
g. Crankshaft journals may be ground	.002", .010", .020", .030" or .040" undersize
h. Fit of crankshaft gear on crankshaft	.001" - .003" tight
7. Main Bearings	
a. Number used	7
b. Type	Replaceable Precision
c. Inside diameter of front, intermediate, center, and rear bearing (with capscrews tightened to specified torque)	3.2499" - 3.2516"
d. Diameter of crankshaft main bearing journals	3.247" - 3.248"
e. Bearing-to-journal clearance at front, intermediate, center, and rear bearings (with capscrews tightened to specified torque)	.0019" - .0046"
f. Overall length of main bearings	
Front and intermediate	1.432" - 1.442"
Center	1.682" - 1.692"
Rear	1.682" - 1.692"
g. Undersize bearings available for service	.002", .010", .020", .030" and .040"
h. Separate type thrust flanges	Available in standard size and .005", .010", .015" oversize
i. Front, intermediate, center, and rear bearing wall thickness (standard bearings)	.1549" - .1554"
j. Bearing bore in cylinder block (without bearing, cap in place, and capscrews tightened to specified torque)	3.5607" - 3.5614"
k. Torque for tightening main bearing capscrews 5/8" - 11 U.N.C., 2A rolled thread	170 - 190 lb ft
8. Connecting Rod Bearings	
a. Type	Replaceable Precision
b. Inside diameter of bearing (with capscrews tightened to specified torque)	2.7495" - 2.7510"
c. Diameter of crankshaft connecting rod journals	2.7475" - 2.7485"
d. Connecting rod bearing-to-journal clearance (with capscrews tightened to specified torque)	.001" - .0035"
e. Overall length of connecting rod bearings	1.195" - 1.205"
f. Undersize bearings available for service	.002", .010", .020", .030" and .040"
g. Bearing wall thickness (standard bearing)	.10975" - .11025"
9. Connecting Rods	
a. Type - non-rifled drilled	Balanced Forged
b. Bolts used per rod	2
c. Connecting rod length (center-to-center)	8.498" - 8.502"
d. Inside diameter of connecting rod bushing (finished bore)	1.5027" - 1.5032"
e. Outside diameter of connecting rod bushing	Split Type
f. Bearing bore (without bearing, cap in place, and capscrews tightened to specified torque)	2.9700" - 2.9705"
g. Connecting rod bearing-to-crankshaft journal clearance (with capscrews tightened to specified torque)	.001" - .0035"
h. Connecting rod width at lower end	1.555" - 1.557"
i. Side clearance-to-crankshaft journal	.005" - .010"
j. Piston pin diameter	1.5015" - 1.5017"
k. Piston pin bushing length in connecting rod	1.490" - 1.510"
l. Piston pin to connecting rod bushing clearance	.001" - .0017"
m. Torque for tightening connecting rod capscrews	65 - 70 lb-ft
n. Bore in connecting rod for piston pin bushing	1.6250" - 1.6255"

DESCRIPTION	SIZE OF NEW PARTS
10. Exhaust Valves	
a. Valve lift (at valve) w/ .015" lash	.4125"
b. Valve lift (at cam)	.285"
c. Seat angle	45°
d. Valve seat contact width	3/32"
e. Valve lash (cold)	.018"
f. Valve lash (engine coolant at normal operating temperature)	.015"
g. Head diameter	1.677" - 1.687"
h. Overall length	6.017"
i. Stem diameter	.3705" - .3710"
j. Valve must be recessed (in head)	.053" min

11. Exhaust and Intake Valve Springs

	Spring Only	Spring w/Damper
a. Valve spring free length	2-17/32" approx.	2-17/32" approx.
b. Valve spring length (valve closed)	2.237"	2.237"
c. Valve spring length (valve open)	1.780"	1.780"
d. Spring load at 2.237" length	38 - 42 lb	40 - 46 lb
e. Spring load at 1.780" length	95 - 105 lb	105 - 115 lb

NOTE: Install new spring when old spring is 5% below the low limit or 5% above the high limit.

12. Intake Valves

a. Valve lift (at valve) w/.015" lash	.462"
b. Valve lift (at cam)	.318"
c. Seat angle	30°
d. Valve seat contact width	3/32"
e. Valve lash (cold)	.018"
f. Valve lash (engine coolant at normal operating temperatures)	.015"
g. Head diameter	1.834" - 1.844"
h. Overall length	6.066"
i. Stem diameter	.3715" - .3720"
j. Valve must be recessed in head	.054" min

13. Exhaust Valve Seat Inserts

a. Seat angle	45°
b. Seat contact width	3/32"
c. Seat run-out	.002"
d. Insert press fit	.001" - .003"
e. Insert O.D. not installed	1.667" - 1.668"
f. Bore in cylinder head for insert	1.665" - 1.666"
g. Depth of counterbore in cylinder head for insert (from bottom deck of head)	.4735" - .4755"
h. Oversize insert	.005" over standard

14. Intake Valve Seat Inserts (Service Only)

NOTE: Production engines do not have intake valve inserts.

a. Seat angle	30°
b. Seat width	3/32"
c. Seat run-out	.002"
d. Insert press fit	.001" - .003"
e. Insert O.D. not installed	1.816" - 1.817"
f. Bore in cylinder head for insert	1.814" - 1.815"
g. Depth of counterbore in head for insert (from bottom deck of head)	.4585" - .4605"

DESCRIPTION	SIZE OF NEW PARTS
15. Exhaust and Intake Valve Guides	
a. Length	2-7/8"
b. Inside diameter ream after assembly	* .373"
c. Stem-to-guide clearance after reaming	
Exhaust	.0020" - .0025"
Intake	.0010" - .0015"
d. Guide stand-out from bottom of counterbore in cylinder head	
Exhaust	1-3/32"
Intake	25/32"

> * NOTE: Valve guides in new production and new factory service heads do not require reaming in the field. They are factory bearingized to .3735" - .3740" I.D. after installation and checked with a .37250" to .37254" diameter GO plug, 3" long.

DESCRIPTION	SIZE OF NEW PARTS
16. Rocker Arms - With Non-Replaceable Bushings	
a. I.D. of rocker arm bushing (finish bore)	1.001" - 1.002"
b. O.D. of rocker arm shaft	.999" - 1.000"
c. Rocker arm shaft-to-rocker arm bushing clearance	.001" - .003"
d. Rocker arm ratio	1.5:1
e. Plug rocker arm shaft	3/4 - 16 U.N.F. - 2B
f. Restrictor elbow - flywheel end	1/16"
17. Camshaft	
a. Number of bearings used	6
b. I.D. of camshaft bearing (when installed)	2.133" - 2.136"
c. O.D. of camshaft journals	2.130" - 2.131"
d. Camshaft bearing-to-journal running clearance	.002" - .006"
e. O.D. of camshaft bearings	2.263" - 2.265"
f. Bore in cylinder block for bearing	2.259" - 2.260"
g. Fit of camshaft bearings in bore of cylinder block	.003" - .006" tight
h. Overall width of camshaft bearings	
Front	1-3/8"
Intermediates	1"
Rear	1"
i. Camshaft end play	.003" - .009"
j. Camshaft gear width	1"
k. Fit of camshaft gear on camshaft	.0015" - .003" tight
l. Specified thickness of thrust collar	.205" - .206"
18. Valve Lifters	
a. Bore in cylinder block for valve lifter	.7495" - .7505"
b. O.D. of valve lifter stem	.7480" - .7485"
c. Fit of valve lifter in bore of cylinder block	.001" - .0025"
19. Front Gear Train	
a. Crankshaft gear to camshaft gear	.0015" - .009"
b. Crankshaft gear to idler gear	.0015" - .0085"
c. Fuel pump drive gear to fuel pump driven gear	.002" - .0095"
d. Camshaft gear to hydraulic pump gear	.003" - .011"
20. Cylinder Head	
a. Valve sequence (front to rear)	Exhaust - Intake

DESCRIPTION	SIZE OF NEW PARTS
21. Lubricating Oil Pressure Pump	
a. Radial clearance - gears to pump body	.00075" - .00175"
b. End clearance - pump gears	.002" - .0045"
c. I.D. in upper pump body for oil pump drive shaft	.6240" - .6250"
d. O.D. of drive shaft	.6220" - .6225"
e. O.D. of drive shaft for oil pump cover	.6170" - .6175"
f. O.D. of idler shaft	.6180" - .6185"
g. I.D. in cover for drive shaft	.6195" - .6205"
h. Clearance - drive shaft to oil pump cover	.0020" - .0035"
i. I.D. in cover for idler gear shaft	.6185" - .6195"
Fit - Idler gear shaft to cover	.0000" - .0015" loose
j. I.D. in gear driver for drive shaft	.6190" - .6200"
Fit - Drive shaft to gear driver	.002" - .0035" tight
k. Clearance - O.D. of drive shaft to bore in oil pump body	.0015" - .003"
l. I.D. in lower pump body for idler gear shaft	.616" - .617"
Fit - Idler gear shaft to body	.001" - .0025" tight
m. I.D. in idler gear	.6190" - .6210"
n. Clearance - Idler shaft to gear	.0005" - .0030"
o. Bore in lower pump body for bushing	1.000" - 1.0005"
p. O.D. of bushing	1.0015" - 1.0020"
Fit - Bushing to oil pump body	.001" - .002" tight
q. I.D. of bushing after pressing into pump body	.6235" - .6255"
r. Clearance shaft to bushing	.0010" - .0035"
s. I.D. in drive bear - for drive shaft	.6205" - .6215"
Fit - Shaft-to-drive gear	.0005" - .002" tight
22. Water Pump	
a. Clearance - impeller to plate	Set w/.015" feeler gauge
b. Bearing	
Bearing O.D.	1.4995" - 1.5000"
Bore in water pump body (for bearing)	1.498" - 1.499"
Fit - Bearing O.D. to body	.0005" - .001" tight
c. Impeller	
Bore in impeller for shaft	.6225" - .6235"
Shaft diameter	.6262" - .6267"
Fit - Shaft diameter to impeller bore	.0027" - .0042" tight
d. Hub - for water pump pulley	
Bore in hub for shaft	.7435" - .7445"
Shaft diameter	.7460" - .7465"
Fit - Shaft diameter to hub bore	.0015" - .0030" tight
23. Idler Gear Assembly	
a. Idler gear bearing	
Bearing bore (I.D. for idler shaft)	1.000" - 1.0008"
Shaft diameter	.9990" - 1.0000"
Fit - Shaft to bearing	.0000" - .0018" loose
Bearing O.D.	1.980" - 1.981"
Bore in idler gear	1.9785" - 1.9795"
Fit - Bearing O.D. to idler gears	.0005" - .0025" tight
Bore in cylinder block for idler gear shaft	.998" - .999"
Idler shaft O.D.	.9990" - 1.000"
Fit - Idler shaft to bore in cylinder block	.0000" - .002" tight
24. Hydraulic Pump Drive Assembly	
a. Hydraulic pump drive bearing	
Bearing bore (I.D. for hydraulic pump drive shaft)	1.500" - 1.5005"
Shaft diameter	1.4995" - 1.5005"
Fit - Shaft to bearing	.0005" - .0010" loose
Bearing O.D.	2.5625" - 2.5635"

DESCRIPTION	SIZE OF NEW PARTS
Bore in hydraulic pump drive housing for bearing	2.5635" - 2.5645"
Fit - Bearing O.D. to hydraulic pump drive housing	.0000" - .002" loose
25. Adaptor Assembly - Fuel Injection Pump Mounting	
a. Bearing adaptor	
O.D. of bearing	1.0650" - 1.0655"
Bore in adaptor for bearing	1.063" - 1.064"
Fit- Bearing-to-bore in adaptor	.001" - .0025" tight
Bore in bearing after pressing into adaptor	.875" - .877"
Shaft diameter	.8735" - .8740"
Clearance - shaft-to-bearing	.001" - .0035"

B. TORQUE SPECIFICATIONS - BOLT, CAPSCREW, AND NUT

The torque values tabulated below have been calculated for specific applications. SAE standard torque values must not be used where those listed in this table apply.

NOTE: Torque values are in pound-feet except where pound-inches is specified. All torque values in this table are calculated for threads lubricated with oil.

Type	Qty.	Description	Size and Thread	Grade	Torque Lb-ft
Caps	14	Bearing Cap, Main	5/8-11 x 4-1/4	8	170-190
Caps	12	Connecting Rod Cap	(Hi-R-Thread) 7/16-20 x 2-1/4	CS-8	65-70
Caps	20	Cyl. Head Mtg. (Short)	9/16-12 x 5-1/16	8	130-140
Caps	6	Cyl. Head Mtg. (Long)	9/16-12 x 8-1/8	8	130-140
Caps	10	Cyl. Head Cover	1/4-20 x 5/8	2	3-4
Nut	1	Fuel Inj. Pump Shaft Retaining	Special	-	35-40
Nut	6	Nozzle Retaining	Special	-	40-60
Nut	6	Nozzle Cap (Lock)	7/8-20	-	75-90
Nut	6	Nozzle Holder Cap	7/8-20	-	75-90
Nut	6	Nozzle Fuel Line	Ermetto Nut	-	20-25
Plug	2	Rocker Arm Shaft-Plug	3/4-16	2	40
Nut	4	Turbocharger Mtg.	3/8-16	Stn. Stl.	18-21
Nut	1	Turbo. Turbine Hsg. Clamp Nut	10 - 32	-	5-10 lb-in.
Caps	6	Turbo. Compressor Housing to Bearing Housing	1/4-20 UNC-2B	-	80-100 lb-in.
Nut	1	Turbo. Impeller	5/16-24 NF-2	-	80-100 lb-in.
Caps	4	Turbo. Diffuser to Turbine Housing	3/8-16 UNC-2B	-	28-33
Plug	2	Turbo. Bearing Housing Pipe Plug	1/2-14 NPTF	-	140-200 lb-in.
Caps	1	Water Pump and Alternator Mounting	3/8-16 x 2-3/16	2	18-21

The heads of capscrews used in Allis-Chalmers engines bear grade marks conforming to standards specified by the Society of Automotive Engineers (SAE). The three grades of capscrews used in Model 3400 and 3500 engines are identified as follows: Grade 2, no marks; Grade 5, three marks, 120° apart; Grade 8, six marks, 60° apart. (See figures in table below.)

Capscrew Size	Pounds Foot *					
	Grade 2 ⬡		Grade 5 ⬡		Grade 8 ⬡	
	NC	NF	NC	NF	NC	NF
1/4"	5-7	6-8	9-11	11-13	12-14	14-16
5/16"	11-13	13-15	18-20	21-23	25-27	28-30
3/8"	18-21	19-22	28-33	30-35	41-46	43-48
7/16"	30-33	32-35	44-49	50-55	69-74	72-77
1/2"	45-50	45-50	68-73	68-73	95-105	95-105
9/16"	60-65	60-65	95-105	95-105	130-140	130-140
5/8"	75-85	75-85	125-135	125-135	170-190	170-190
3/4"	125-135	125-135	210-230	210-230	290-310	290-310
7/8"	105-115	105-115	290-310	290-310	450-500	450-500
1"	140-150	450-475	380-410		600-630	

* All torque values in this table are calculated for threads lubricated with oil.

CAUTION: The SAE standard torque values tabulated above are for use when specific torque data is not available. Do not use these values in place of those specified elsewhere in this manual.

C. STUD GAUGE HEIGHTS

Description	Stud Size				Gauge Height	Torque Lb-ft *
	Dia.	Thread		Length		
		Stud End	Nut End			
Nozzle Mounting to Cylinder Head	5/16	18	24	1-31/32"	1-15/32"	7-22
Fuel Injection Pump to Adaptor	3/8	16	16	1.42"	15/16"	10-35

* Torque values in this table are calculated for threads lubricated with oil.

TOPIC 11. COOLING SYSTEM

A. GENERAL

The engine cooling system includes the water pump, radiator, water inlet piping, thermostat, thermostat housing, engine oil cooler, (turbocharger engine) hoses, engine coolant temperature gauge, cooling fan, coolant filter (optional), and water passages in the cylinder block and cylinder head.

The cooling system is pressurized by a 7 psi pressure cap. By pressurizing the system, the normal boiling point of 212° F of clean water at sea level is raised approximately 3° F per psi. Consequently, coolant in the system at sea level will not boil until a temperature of 212° F, plus 21° F, or a total of 233° F is reached. Temperatures above this figure will cause loss of coolant and result in engine overheating. Altitude affects the point at which coolant will boil, that is, the higher the altitude, the sooner (lower temperature) the coolant will boil. To estimate coolant boiling point at various altitudes above sea level, deduct 1-1/2° F per 1000 ft altitude, from 233° F, the boiling point established with a pressure cap at sea level.

A double-acting valve in the radiator pressure cap relieves air pressure caused by expansion of heated coolant, and allows atmospheric pressure to enter when cooling contraction occurs. Because this is a pressure-type cooling system, it is necessary to keep the radiator cap turned on tightly at all times to prevent loss of pressure.

> WARNING: Do not remove radiator filler cap while coolant temperature is near 212° F or above because it will boil violently and may splash on person removing the cap.

B. GENERAL MAINTENANCE

In warm weather keep the cooling system filled with clean, soft water or rain water. If soft water is not available and hard water must be used, it must first be treated with a water softener. A rust inhibitor, available at "Allis-Chalmers" dealers, should be added to the water for warm weather operation. As optional equipment, a coolant filter is available to maintain a clean cooling system and thereby extend engine life.

Also if soft water is not available and hard water must be used, no harmful condition will develop in the cooling system if the coolant filter (optional equipment) is operating efficiently. An ion exchange resin in the element removes water hardness components from the coolant and prevents formation of scale on metal surfaces in the cooling system. Soluble oil or rust inhibitor is not recommended for use in the engine under normal operating circumstances because the coolant filter provides a rust, scale, and corrosion-free cooling system without their use.

In winter weather use a glycol base permanent antifreeze solution in the system to protect against damage from freezing. After any addition of water or antifreeze compound, test the solution after it has become thoroughly mixed to ensure it will withstand prevailing or anticipated temperatures.

> CAUTION: Do not use antifreeze solutions that are harmful to aluminum.

Refer to instructions on protection charts furnished by the antifreeze manufacturer for information on quantity required for lowest anticipated temperature. Usually a mixture of 64% glycol-base antifreeze and 36% water provides maximum protection. Keep radiator air passages free of leaves, trash, and other material that may restrict flow of air through the radiator.

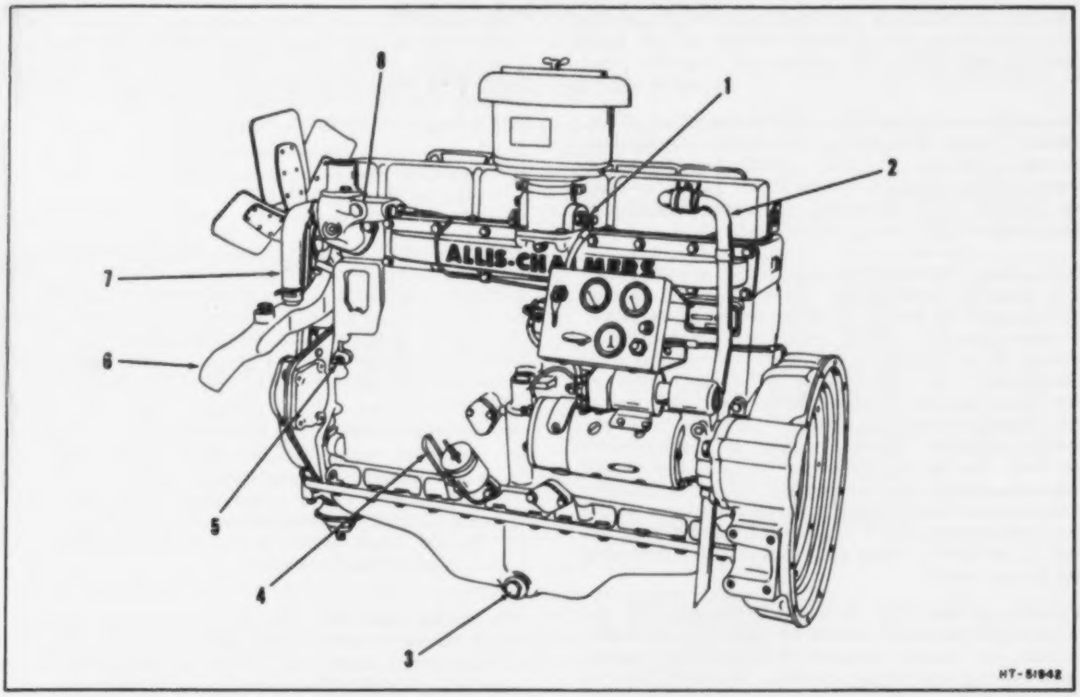
> CAUTION: Keep cylinder head capscrews, water pump mounting capscrews, hose clamps, and fitting connections tight. Correct all leaks as soon as they become evident. Inspect hoses carefully and replace them if they have deteriorated.

The engine operates most efficiently when coolant temperature is 180° F minimum. Operation with low coolant temperature will result in incomplete fuel combustion, higher fuel consumption with less power, and formation of harmful deposits in the engine. A properly functioning thermostat is required to maintain normal coolant temperature. If the coolant temperature is consistently below 180° F, the thermostat should be removed, checked for proper operation, and replaced if necessary.

C. DRAINING COOLING SYSTEM

1. If engine is installed in portable type equipment, make certain it is in a level position to assure complete draining.
2. Remove radiator filler cap and open radiator drain cock.
3. Open drain cock located on left side of cylinder block at front or rear end of engine, depending on application.
4. If engine is equipped with coolant filter, leave filter shutoff valves open.
5. Remove drain plug from coolant filter body.
6. If applicable, remove drain plug from engine oil cooler.
7. If applicable, open air compressor drain cock.

> CAUTION: When draining cooling system in freezing weather, make certain coolant flows freely from drains and that the system drains completely.



1. Air Heater Element
2. Breather Tube
3. Oil Drain Plug
4. Dipstick
5. Drain Cock
6. Water Inlet Piping
7. Bypass Hose
8. Thermostat Housing

Figure 1. 3500 Engine - Left hand side.

D. FILLING COOLING SYSTEM

1. Close all drains that were opened to drain system. (Refer to Paragraph C above.)

2. Fill system with clean, soft water or antifreeze solution until level is approximately 1-1/2" below bottom of radiator filler neck. Install filler cap.

3. Operate engine for a period of time at normal operating temperature to vent all air from system.

4. Check level of coolant in radiator and, if necessary, add coolant to attain proper level.

E. CLEANING OF COOLING SYSTEM

1. Clean cooling system at beginning of cold weather before antifreeze is added, and again after antifreeze is drained for warm weather operation. Also, drain, flush, and refill system whenever inspection reveals an accumulation of rust and scale.

2. If engine is provided with a coolant filter that has been properly maintained, cleaning of system should not be necessary.

3. Many good solvents are on the market for cleaning of coolant systems; use according to instructions.

CAUTION: Never mix antifreeze compounds or inhibitors with any cleaning, neutralizing, or flushing compounds.

4. If radiator tubes are clogged, reverse flush radiator as follows:

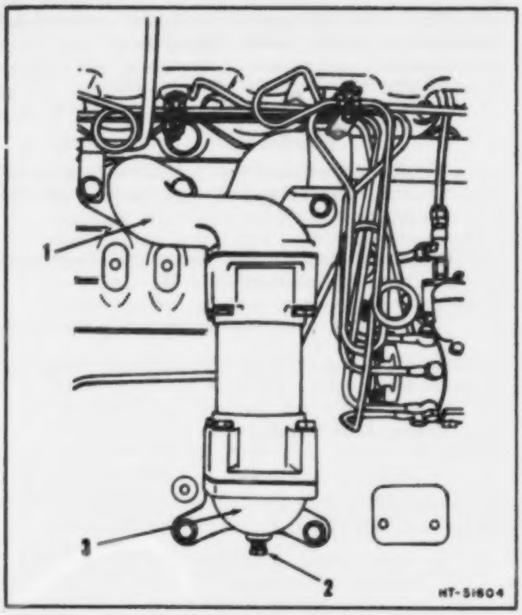
   a. Disconnect upper and lower radiator hoses.

   b. Connect a pressure water hose to lower connection with a suitable adaptor.

   c. Plug upper connection and remove radiator cap.

   d. Force water through radiator. Foreign material will flow out through top of radiator with the water.

CAUTION: Do not use more than 5 or 6 psi pressure when flushing. Excessive pressure may rupture radiator.



1. Oil Cooler Header
2. Drain Plug
3. Bonnet

Figure 2. Engine Lubricating Oil Cooler

5. Keep radiator air passages free of debris and other obstructions. Clean exterior with an air blast carrying a grease solvent of oleum spirits or carbon tetrachloride. If engine is equipped with sucker type fan, direct cleaning spray at rear (fan side) of radiator. For engines having a blower type fan, direct spray at front of radiator.

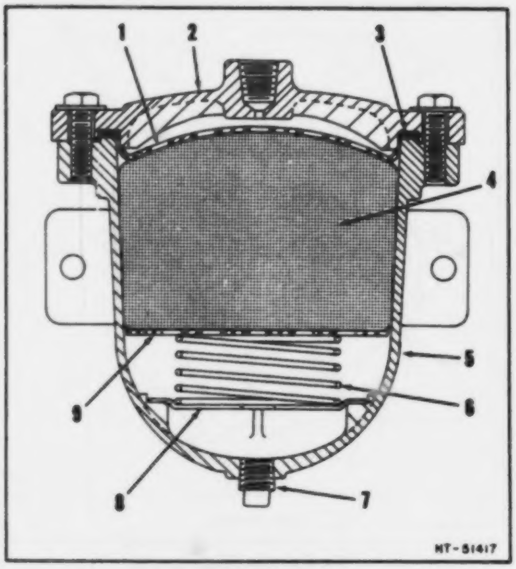
> WARNING: Keep engine covered during cleaning operation. Provide adequate ventilation to avoid toxic effects of the cleaning spray. Never clean with gasoline, fuel oil, or kerosene.

6. After cooling system has been cleaned, flushed, and refilled, inspect entire system for coolant leaks. Correct all leaks found to avoid foaming, corrosion, and loss of solution.

F. COOLING SYSTEM FILTER

If engine is equipped with a coolant filter, do not use soluble oil or other conditioners in the cooling system. However, filter efficiency is not affected by use of permanent type antifreeze in the system.

> CAUTION: If a leak stopper is added to the coolant, do not allow it to circulate through the filter. Shutoff valves are provided in inlet and outlet lines for isolating the filter from remainder of cooling system.

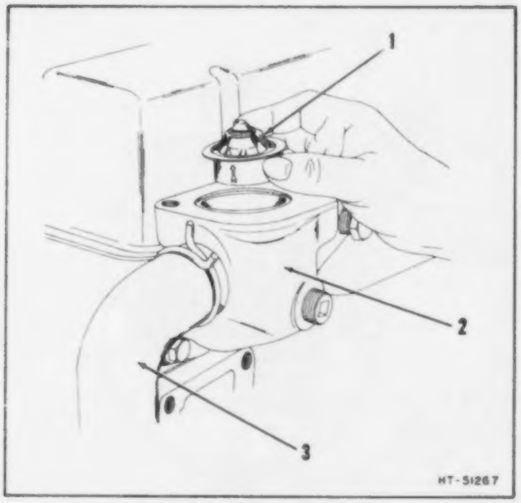


1. Upper Plate
2. Cover
3. Gasket
4. Filter Element
5. Body
6. Spring
7. Drain Plug
8. Sump Plate
9. Lower Corrosion Resistor Plate

Figure 3. Coolant Filter

At each 300 to 500 hour interval of operation, depending on conditions, service the coolant filter as follows:

1. Thoroughly clean filter body and surrounding area.
2. Close coolant inlet and outlet shutoff valves.
3. Remove drain plug from bottom of filter body and drain coolant.
4. Remove capscrews attaching filter cover to body and remove cover.
5. Lift upper plate and filter element out of filter body. Discard filter element.
6. Remove lower corrosion resistor plate and spring from filter body.
7. Inspect and clean lower corrosion resistor plate, buffing it to a bright finish. If plate is thin and pliable, or has developed holes, replace it.
8. Remove and clean sump plate. Clean sump area in filter body.
9. Install sump plate, spring, and lower corrosion resistor plate.



1. Thermostat
2. Thermostat Housing
3. Bypass Hose

Figure 4. Installing Thermostat

10. Install new filter element.

> NOTE: For most efficient filter performance, use the borate inhibited element when permanent antifreeze is used in the system, and the chromate inhibited element when plain water is used in the system.

11. Position upper plate in filter body.
12. Make certain gasket is in good condition, then install cover and secure with attaching capscrews.
13. Replace drain plug and open inlet and outlet shutoff valves.

G. THERMOSTAT

The thermostat is the bypass type and is located on the left side and front of the engine (See Figure 1). It is so positioned in the system that when closed, coolant flow from the engine to the radiator is completely shut off. Coolant is then directed from the engine through the water bypass tube to the inlet side of the water pump, then back through the engine circulating system. When coolant temperature reaches 180° F the thermostat starts to open allowing coolant to pass to the radiator, as well as through the engine circulating system.

Replacement of the thermostat is necessary when the thermostat becomes corroded and sticks in the open or closed position. If the engine overheats or does not reach and maintain a minimum temperature of 180° F., the thermostat should be removed and tested as a possible cause of trouble.

1. Thermostat Removal
   a. Drain cooling system.
   b. Remove capscrews and lockwashers securing water outlet flange to top of thermostat housing.
   c. Raise water outlet flange with hose intact and position it to one side.
   d. Remove outlet flange gasket and thermostat.
   e. Clean and inspect thermostat flange and housing.
2. Thermostat Testing
   a. Suspend thermostat in a pan of clean water. Thermostat must be completely immersed but not touching bottom of pan.
   b. Heat water gradually and stir so heat is evenly distributed.

> CAUTION: Check temperature of water with a reliable thermometer. Do not overheat.

   c. Observe thermostat as temperature of the water increases. If the thermostat is functioning properly, it should begin to open between 175 to 182° F and be fully open at 202° F. The amount of travel between open and closed positions of the thermostat should be a minimum of .260".
   d. The thermostat is not adjustable. If it does not operate within the above limits it must be replaced.
3. Thermostat Installation.
   a. Install thermostat in thermostat housing with arrow stamped on thermostat pointing up.
   b. Using new outlet flange gasket, position it on top of the thermostat housing.
   c. Inspect water outlet flange and clean if necessary.
   d. Position water outlet flange on thermostat housing and secure with lockwashers and capscrews. Tighten capscrews to a torque of 44 to 49 lbs. ft.
   e. Refill cooling system as detailed in Paragraph D, this topic.

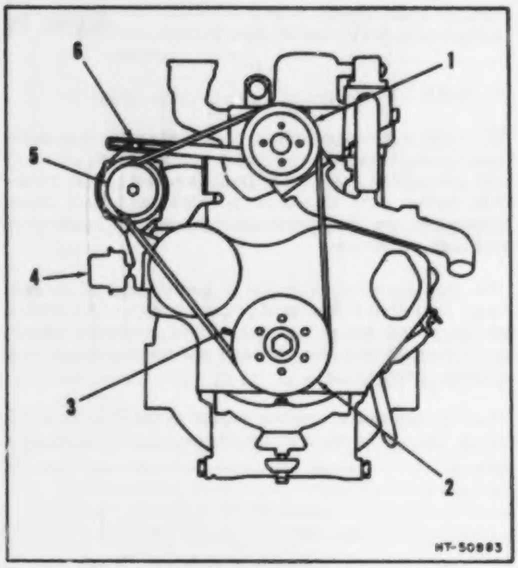
H. BELTS AND ADJUSTMENT

Depending on the type of fan used, air is pushed or pulled through the radiator, which in turn, reduces the temperature of engine coolant as it circulates from top to bottom of the radiator core. The alternator and water pump, as well as the fan, mounted on the water pump pulley, are driven simultaneously by the crankshaft pulley with an identical, matched pair of belts.

1. Inspect drive belts frequently.
2. Replace belts if they are damaged, badly worn, or soaked with oil and grease. Even though only one belt may need replacement because of damage or excessive wear, it is imperative that both belts be replaced to obtain satisfactory belt life. After replacement, approximately 24 hours operating time is required to properly seat a new pair of belts.
3. Check tension of both drive belts. They should have a good spring when pressed with the hand; or, belts are properly adjusted when they can be pressed inward 1/4" to 1/2" at a point halfway between the alternator pulley and crankshaft pulley.
4. To obtain proper belt tension, loosen the alternator adjusting brace capscrew and move alternator in or out as required.

> CAUTION: When adjusting belt tension, apply force against stator laminations between alternator end frames, not against the end frames.

5. Retighten the adjusting brace capscrew.



1. Water Pump Pulley
2. Crankshaft Pulley
3. Timing Pointer
4. Voltage Regulator
5. Alternator Pulley
6. Adjusting Brace Capscrew

Figure 5. Belt Adjustment

TOPIC 12. FUEL SYSTEM

A. GENERAL

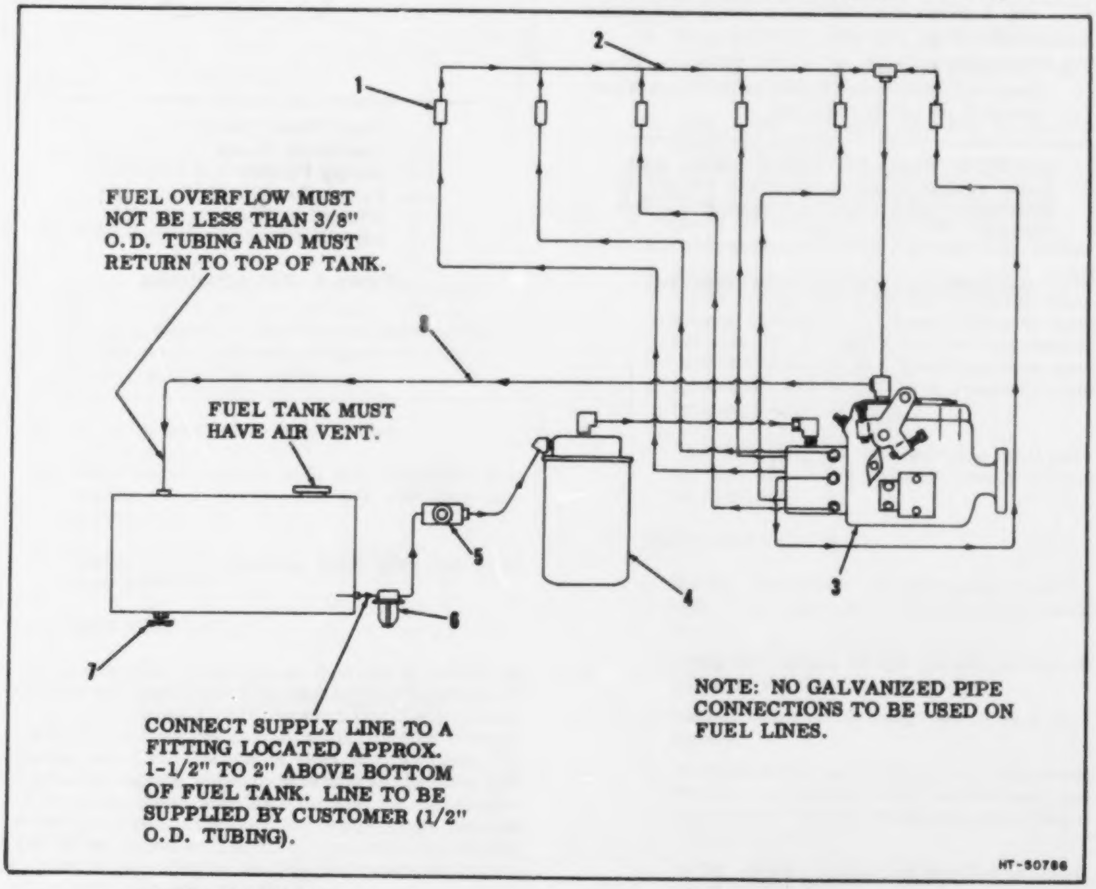
The fuel system consists of a fuel tank, fuel sediment bowl, hand primer pump, combination primary and secondary fuel filter, transfer pump, fuel injection pump, fuel injection nozzles, and fuel lines. There are two fuel pressure systems, low pressure and high pressure.

The low pressure system is comprised of the fuel tank, sediment bowl, hand primer pump, combination primary and secondary fuel filter, transfer pump, fuel lines between the fuel tank and the fuel pump, and leakage return lines.

The high pressure system begins in the fuel injection pump where the fuel is forced by the action of cam-actuated plungers into the outlet ports and thru the high pressure fuel lines connected to the fuel injection nozzles.

The fuel is drawn from the fuel tank thru the fuel sediment bowl, the hand primer pump, and the combination primary and secondary fuel filter by the transfer pump located at the rear of the fuel injection pump. The fuel is then forced by the transfer pump to the cam-actuated plungers which force the fuel under high pressure thru the fuel lines to the fuel injection nozzles from which the fuel enters the combustion chambers in the form of four, fine, cone shaped sprays.

The fuel transfer pump delivers more fuel to the fuel sump of the fuel injection pump than is required for



FUEL OVERFLOW MUST NOT BE LESS THAN 3/8" O. D. TUBING AND MUST RETURN TO TOP OF TANK.

FUEL TANK MUST HAVE AIR VENT.

CONNECT SUPPLY LINE TO A FITTING LOCATED APPROX. 1-1/2" TO 2" ABOVE BOTTOM OF FUEL TANK. LINE TO BE SUPPLIED BY CUSTOMER (1/2" O.D. TUBING).

NOTE: NO GALVANIZED PIPE CONNECTIONS TO BE USED ON FUEL LINES.

1. Nozzle Injectors
2. Drip Manifold
3. Fuel Injection Pump
4. Combination Fuel Filter
5. Hand Primer Pump
6. Fuel Sediment Bowl
7. Drain Cock
8. Fuel Return Line

Figure 1. Fuel System Schematic

engine operation. A line extending from the top of the fuel injection pump to the fuel tank conveys the surplus fuel back to the fuel tank.

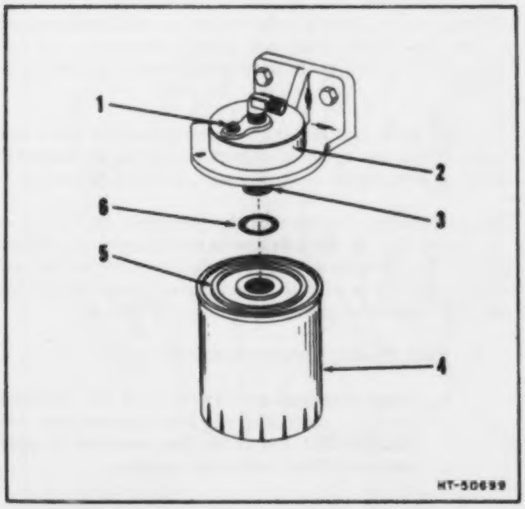
There is a certain amount of fuel seepage between the lapped surfaces of each fuel injection nozzle valve and its body, which is necessary for lubrication. This leakage of fuel accumulates around the spindle and in the spring compartment of each fuel injection nozzle holder and is returned through the fuel drip manifold to the fuel return line, extending to the fuel tank. The excess fuel delivered to the fuel injection pump by the fuel supply pump is also returned to the fuel tank through the fuel return line.

A regulating valve in the pump end plate allows a large percentage of the fuel to be bypassed back to the inlet side. The fuel bypassed increases in proportion to speed, and the regulating valve is designed so the transfer pump pressure also increases with speed.

If necessary precautions are not taken in the storage of fuel, in the transfer of fuel to the fuel tank, and in keeping the fuel tank full to prevent condensation, foreign matter and water will enter the fuel system and damage the fuel injection pump and fuel injection nozzles. The fuel filter is installed in the fuel injection system to clean the fuel before it enters the fuel injection pump.

It is essential that personnel responsible for the care and operation of the engine adhere to the following maintenance recommendations:

1. Use only fuel meeting the specifications as outlined in Topic 7.



1. Vent Plug
2. Filter Head
3. Threaded Insert
4. Fuel Filter
5. Gasket
6. O-ring

Figure 2. Fuel Filter

2. Store and handle fuel with utmost care to prevent water and foreign matter from entering the fuel system.
3. Properly maintain fuel oil filter.
4. Remove injection nozzle holder assemblies at the prescribed intervals; adjust the opening pressure and check the spray pattern.
5. Daily, drain the water from the fuel sediment bowl.
6. Periodically check injection pump timing.
7. Keep all fuel line connections, filter, injection pump and injection nozzle holder assemblies tightened securely to the engine (specified torque).
8. Before removing any part of the fuel injection system from the engine be sure to wash the part with cleaning solvent, also the surrounding area to prevent the entrance of abrasives into the system. Cover all openings immediately.

B. FUEL FILTER

The combination primary and secondary fuel filter is the disposable, throw-away type. Any dirt or sediment that passes through the primary portion of the filter is collected by the secondary portion and prevented from entering the fuel injection pump.

1. Filter Service

Close the sediment bowl shutoff valve and remove bowl daily before start of operation during warm weather, and shortly after end of days operation during freezing weather. Dump out water and sediment, clean bowl and screen, and replace bowl securely. Inspect for leaks and replace gasket when necessary. Remove and discard filter and O-ring and install new filter and O-ring after each 500 hour interval of operation (more often when operating conditions warrant), or when filter becomes clogged. A clogged filter is usually indicated by irregular engine performance.

2. Fuel Filter Replacement

a. Clean all dirt from around filter, filter head, and surrounding area.

NOTE: Close sediment bowl shutoff valve if fuel level in tank is above level of fuel filter.

b. Unscrew by hand and remove filter and O-ring from filter head. Discard filter and O-ring.

c. Clean dirt and sediment from filter head.

d. Position new O-ring from filter replacement kit on threaded insert in filter head.

Screw new filter by hand into position until gasket contacts base of filter head. Using hand pressure, tighten filter 1/2 to 3/4 of a turn more.

> CAUTION: Do not use any tools to tighten filter. Do not use sealing compounds or lubricants. Always use an Allis-Chalmers replacement filter.

e. Open shutoff valve on fuel sediment bowl and vent the low pressure system. Refer to Paragraph C, below.

> CAUTION: Keep parts clean when changing the fuel filter.

C. VENTING FUEL SYSTEM

1. Venting Low Pressure Fuel System

a. Loosen filter vent plug located on top of filter head. (See Figure 2.)

b. Open shutoff valve on fuel sediment bowl.

c. Loosen locking screw on top of hand primer pump plunger and move clamp to one side.

d. Move primer plunger back and forth in a pumping motion to fill the filter with fuel and expel the air.

e. When flow of fuel around vent plug is free of air bubbles, tighten vent plug securely.

f. Position primer pump plunger clamp and retighten locking screw.

2. Venting High Pressure Fuel System

The high pressure fuel system is usually self-venting due to the fact that air trapped by the fuel injection pump is forced out through the injection nozzles and into the combustion chambers. However, if the engine has run out of fuel or has been shut down for an extended period of time, or if the fuel lines have been removed, it may be necessary to vent the high pressure system to facilitate engine starting. Proceed as follows:

a. Loosen fuel line connection nut attaching each line to its corresponding fuel nozzle-holder.

b. Place throttle in high speed position and turn on key switch.

c. Crank engine with starter until fuel flows from ends of all high pressure fuel lines. Connect fuel lines to nozzle-holders and tighten connection nuts.

> CAUTION: Do not operate starting motor continuously for more than 30 seconds at a time without a pause of two minutes to permit starter to cool.

D. FUEL INJECTION PUMP

The single-cylinder, distributor type fuel injection pump incorporates inlet metering and opposed plungers that are operated by an internal cam ring. It is designed for self-lubrication by the fuel oil supply. Purpose of the pump is to accurately meter and deliver quantities of fuel under high pressure to injection nozzles through which the fuel is introduced into the engine combustion chambers at a definite timing in relation to the engine firing cycle and within the required injection period.

An integral governor of the mechanical-centrifugal type controls fuel delivery and, therefore, engine speed. The governor is driven directly off of the pump drive shaft without gearing. The direction of rotation of the drive shaft is clockwise.

The transfer or supply pump, in the opposite end of the rotor from the pumping cylinder, is of the positive displacement, vane type and is covered by the end-plate.

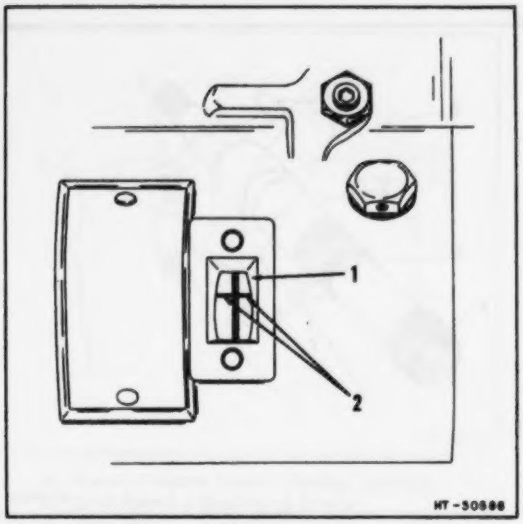
Fuel shutoff is accomplished by turning off the key switch. The electric solenoid mechanism within the fuel pump opens or closes the metering valve to permit or stop the flow of fuel to the engine. Normally, the electric solenoid mechanism is of the energized to run type (open when energized); however, the energized to stop type is also available on special quotation.

The standard fuel injection pump governor has a 10% regulation. An optional injection pump is available with an adjustable 3-1/2% speed droop regulation.

No lubrication service on the governor assembly is required and it seldom needs adjustment. If engine speed is irregular, check the fuel system and all other applicable engine adjustments before removing the fuel injection pump assembly for repair.

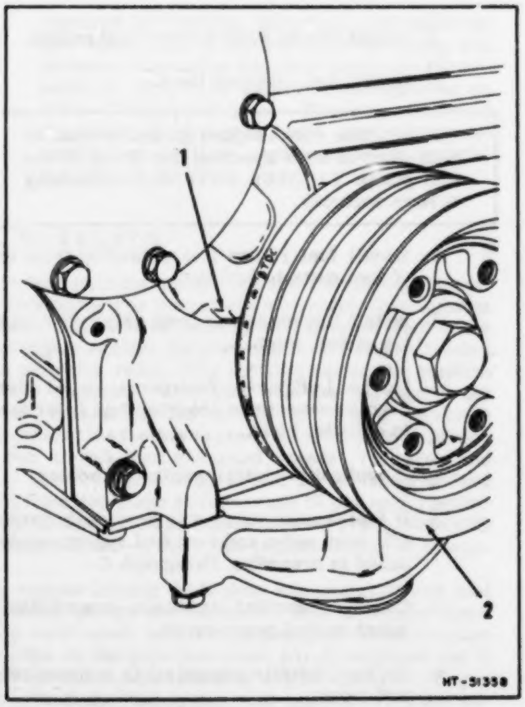
1. Fuel Injection Pump Removal

a. Clean external surfaces of the injection pump, including all line connections and fittings that are to be disconnected to prevent dirt from entering system.



1. **Timing Window**
2. **Timing Marks**

Figure 3. Fuel Pump Timing Marks



1. **Timing Pointer**
2. **Crankshaft Pulley and Damper Assembly**

Figure 4. Front End Timing Marks

b. Rotate engine flywheel until Number 1 piston is near top of its compression stroke and pointer on timing gear cover is aligned with proper number of timing degrees stamped on pulley and damper assembly. Refer to Topic 2, Paragraph D, for timing degrees per engine rpm.

c. Disconnect throttle control cable from speed control lever.

d. Disconnect electrical lead from terminal on fuel pump cover.

e. Shut off fuel supply if the tank or fuel level in tank is above filter.

f. If applicable, remove engine oil cooler.

g. Due to the rigidity of the tubing, it may be necessary to loosen, but do not remove, capscrews securing fuel filter head to cylinder block. Disconnect and remove filter-to-fuel-pump inlet line.

h. Disconnect and remove drip manifold line from top of fuel pump.

i. Disconnect and remove fuel return line from top of fuel pump.

j. Disconnect all high pressure lines from nozzle holders and fuel pump. Loosen, but do not remove, nuts securing two clamps on the high pressure lines. Remove lines and loosened clamps as an assembly from the engine. Cover all openings to prevent entrance of dirt.

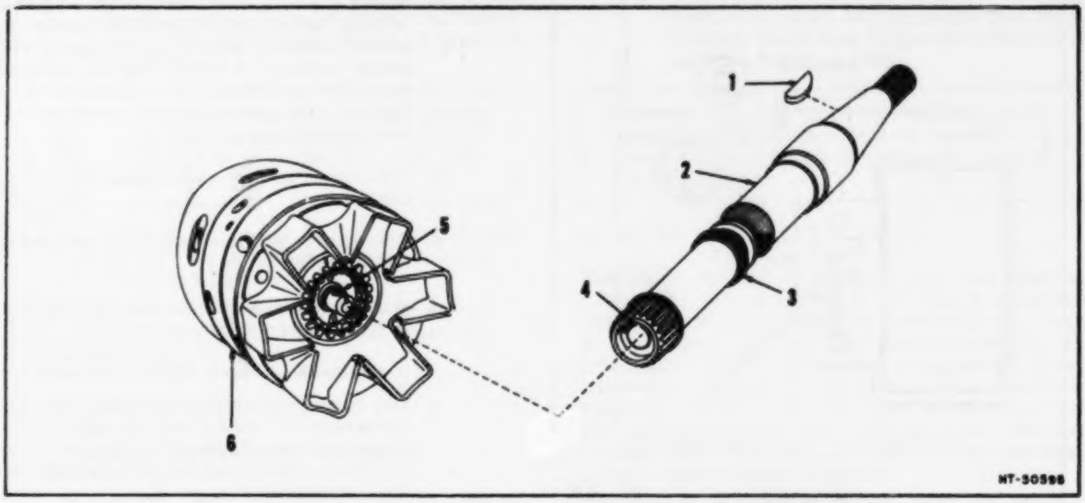
k. Remove two adaptor-to-pump stud nuts and serrated washers. Remove fuel injection pump assembly from the drive shaft, being careful not to damage drive shaft seals.

2. Fuel Injection Pump Installation and Timing

When the fuel injection pump has been serviced and is ready to be reinstalled, or if a new pump is to be installed on the engine, follow the procedure outlined below:

a. Remove timing window cover from the fuel injection pump. Two fuel pump timing marks are used for timing injection of fuel into Number 1 cylinder. One mark is located on governor weight retainer hub and one is located on the cam ring. Insert screwdriver, or other suitable tool, into drive shaft end of pump and turn distributor rotor until timing marks are aligned as viewed through the timing window.

b. Rotate engine flywheel until Number 1 piston approaches top dead center on its compression stroke. This is determined by observing valves of Number 1 cylinder. With both valves closed (valve push rods at bottom of travel), continue to rotate flywheel until pointer on front of timing gear housing cover is aligned with proper number of timing degrees (Figure 4) stamped on the pulley and



1. Key
2. Pump Drive Shaft
3. Seals
4. Internal Groove
5. Internal Tang
6. Hydraulic Head and Rotor Assembly

Figure 5. Fuel Pump Shaft, Head, and Rotor

damper assembly. Refer to Topic 2, Paragraph D, for proper number of timing degrees per engine rpm. Engine is now properly positioned for installation of the fuel injection pump.

c. Inspect pump drive shaft seals and pilot seal. (See Figure 5.) Replace if necessary.

d. Lubricate seals with engine oil or grease. Hold fuel pump in position so vertical center line of pump is approximately in line with scribed mark on flange. Slide pump over drive shaft and on to pump mounting studs using care to prevent damage to seals. Install serrated washers and the adaptor-to-pump stud nuts but do not tighten nuts at this time.

> CAUTION: In order to prevent installation of fuel pump 180° out of time, an internal groove is provided in the splined end of the pump drive shaft. The splined end must be engaged by an internal tang of the fuel pump distributor rotor before drive shaft will engage distributor rotor splines. (See Figure 5.)

e. Turn pump until timing marks are aligned. Tighten attaching stud nuts securely to a torque of 19 to 22 lbs. ft.

> NOTE: Mounting holes in pump housing are elongated so pump can be turned to align timing marks within the timing window.

f. Install timing window cover and gasket.

g. Install fuel injection lines.

> NOTE: Make sure a copper gasket is used on both sides of each injection line fitting at the fuel pump. Tighten nuts and connecting screws securely.

h. Install fuel return line extending from top of fuel pump to fuel tank.

i. Install line extending from drip manifold to top of fuel pump.

j. Install filter-to-fuel-pump inlet line. Tighten capscrews securing fuel filter head to cylinder block.

k. If applicable, install engine oil cooler.

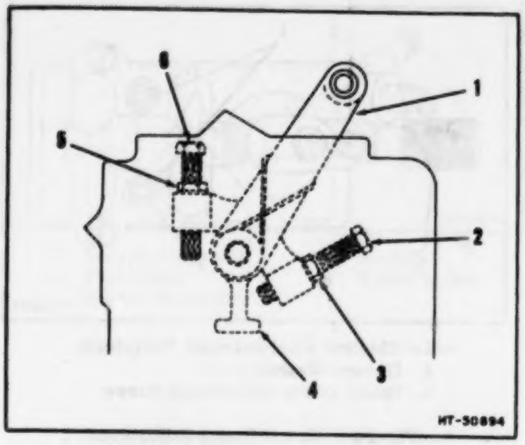
l. If fuel supply valve was previously turned off, open valve and vent fuel system as detailed in preceding Paragraph C.

m. Connect electrical lead to non-grounded terminal on fuel pump cover.

n. Connect throttle control cable to speed control lever.

3. Fuel Injection Pump Adjustments

Allis-Chalmers dealers are equipped with injection pump test stands and the special tools



1. Speed Control Lever (Spring Loaded)
2. Low Speed Adjustment Screw
3. Jam Nut
4. Lever Stop
5. Jam Nut
6. High Speed Adjustment Screw

Figure 6. Engine Speed Adjustment

required for testing, adjusting, and repairing this assembly. If at any time the pump and governor assembly requires repair or adjustment, it should be removed and taken to an Allis-Chalmers dealer. It is important that the dealer be furnished with the pump serial number, as well as engine model and serial number, to facilitate repair.

E. GOVERNOR

The fuel injection pump contains its own mechanical or flyweight-type governor which controls the amount of fuel delivered to the engine. The movement of the flyweights against the governor thrust sleeve rotates the metering valve. The rotation varies the position of the metering valve slot with the passage to the rotor, controlling the flow of fuel. The governor is adjusted at the factory to provide for the proper horsepower at full-load governed speeds. The specified idle speed is from 500 to 600 RPM. The standard fuel injection pump governor has 10 per cent regulation. An optional fuel injection pump is available with an adjustable 3-1/2 percent regulation (speed droop).

All engines leaving the factory are equipped with fuel injection pumps and governors that have been carefully calibrated, adjusted, and sealed. No lubrication service on the governor assembly is required and it seldom needs adjustment. If engine speed is irregular, check the fuel system and applicable engine adjustments before changing the governor setting. Refer to Topic 2, Paragraph F, for standard speed settings.

1. Checking Engine Speed

   a. Run engine until minimum operating temperature is obtained.

   b. Move throttle control to low and high speed positions and make sure the control moves governor speed control lever through its full arc of travel.

   c. Move throttle control to LOW IDLE position. Check engine speed to make certain rpm is within specified range.

   > NOTE: If engine is not equipped with a panel mounted tachometer, use a hand tachometer and hold it against front end of engine crankshaft.

   d. Move throttle control to HIGH IDLE position. Check engine speed to see if rpm is within specified range.

   e. If engine speed is not within ranges specified, governor must be adjusted.

2. Governor Adjustments - Standard 10 Per Cent Regulation

   a. Disconnect throttle control cable from fuel injection pump speed control lever so lever can be moved by hand.

   b. With engine running at minimum temperature, loosen jam nut on the low idle adjusting screw. Hold speed control lever toward front (fan end) of engine so low idle adjusting screw contacts the lever stop. Turn low idle adjusting screw IN to increase or OUT to decrease low idle engine speed. When 500 to 600 rpm is obtained, hold adjusting screw and tighten the jam nut.

   c. Again with engine running at minimum temperature loosen jam nut on the high idle adjusting screw. Hold speed control lever toward rear (away from fan end) of engine so high idle adjusting screw contacts the lever stop. Turn high idle adjusting screw IN to decrease or OUT to increase high idle engine speed. When proper high idle speed is obtained, hold adjusting screw and tighten the jam nut.

   d. Connect throttle control cable to the speed control lever. Make certain lower end is so positioned in the control cable bracket and swivel that when throttle control cable is pushed IN, the control lever low idle adjusting screw contacts the pump housing lever stop. Likewise, when throttle cable is pulled OUT, the high speed adjusting screw also contacts the lever stop.

3. Governor Adjustments - Optional 3-1/2 Per Cent Regulation

An external speed droop adjustment screw at rear of the pump housing (Figure 7) provides precision control of governor sensitivity by decreasing or increasing effective length of the governor control spring. Turning the adjusting screw IN shortens effective length of the control spring, making it less sensitive and increasing the speed droop. Turning the screw OUT has opposite effect. Adjust governor as detailed below:

a. Make low idle and high idle speed adjustments following procedure outlined above for the standard governor.

b. To adjust speed droop:

(1) Operate engine until normal operating temperature is reached.

(2) Apply full load. With engine operating at rated speed, droop is determined by removing load and noting the no-load speed, or in the case of a diesel electric set, by noting its frequency.

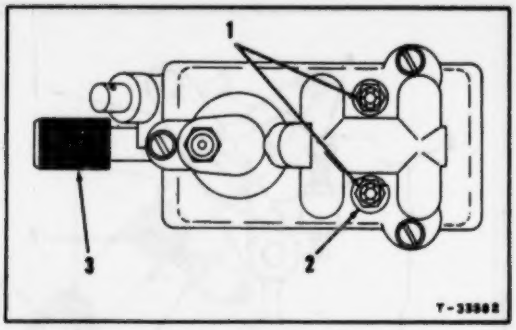
(3) Turn adjusting screw clockwise to increase, or counterclockwise to decrease speed droop. A minor correction of throttle position is also necessary.

NOTE: If speed droop adjusting screw is adjusted to maximum or near maximum droop, severe strain is placed on throttle and governor linkage parts unless throttle control cable or linkage is first disconnected from the pump speed control lever.

F. FUEL INJECTION NOZZLE HOLDER ASSEMBLY

1. Description

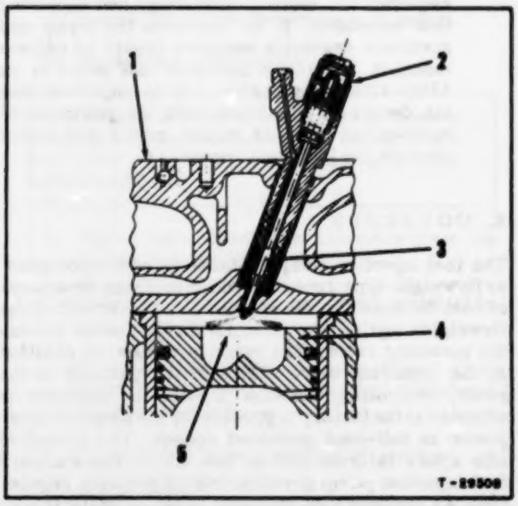
Each engine cylinder is provided with a multihole, differential needle, hydraulically lifted, fuel injection nozzle holder assembly. (See Figure 8.) The function of each nozzle holder assembly is to direct a metered quantity of fuel received from the fuel injection pump into the corresponding engine combustion chamber in a highly atomized, predetermined spray pattern, and in such manner as to produce the most efficient performance.



1. Electric Fuel Solenoid Terminals
2. Ground Washer
3. Speed Droop Adjustment Screw

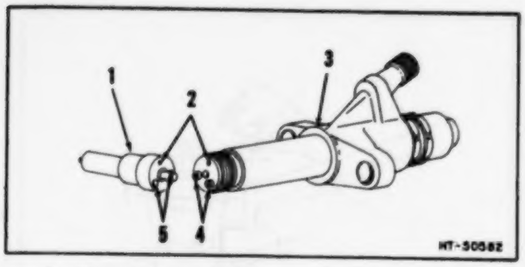
Figure 7. Speed Droop Adjustment

Each fuel injection nozzle holder assembly consists of two assemblies; an injection nozzle holder assembly and an injection nozzle assembly. The holder assembly positions the nozzle in the cylinder head and provides a means of conducting fuel received from the fuel injection pump to the nozzle. The holder consists of a



1. Cylinder Head
2. Fuel Injection Nozzle Holder Assembly
3. Fuel Injection Nozzle
4. Piston
5. Combustion Chamber

Figure 8. Combustion Chamber and Nozzle Holder Location



1. Nozzle Assembly
2. Fuel Ducts
3. Holder Assembly
4. Dowels
5. Dowel Holes

Figure 9. Fuel Injection Nozzle Holder Dowel Location

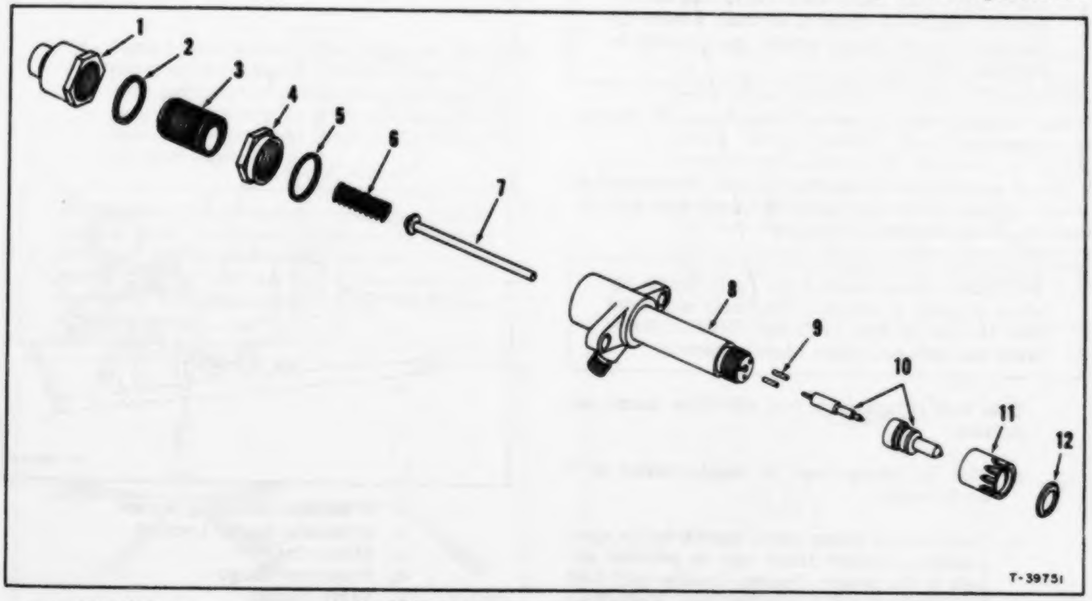
steel holder body, two locating dowels, spindle, spindle spring, pressure adjusting screw, adjusting screw locknut, gaskets, cap nut, and a nozzle retaining nut. The nozzle assembly consists of a nozzle valve and a nozzle body in which are located four spray orifices, equally spaced 90° apart. The nozzle valve is operated hydraulically within the valve body by fuel delivered under pressure by the fuel injection pump. The nozzle is positioned on the holder by two dowels whereby the four spray orifices are fixed on a plane parallel to the piston top, and the nozzle fuel duct is registered with the holder fuel duct.

Fuel enters the nozzle holder fuel inlet passage, passes through the holder fuel duct into the nozzle fuel duct via an annular groove in the nozzle body, and then into the pressure chamber above the nozzle valve seat. At instant the pressure of fuel in the pressure chamber exceeds pressure exerted on the spindle and nozzle valve by the spindle spring, the nozzle valve is lifted off its seat and fuel is forced through orifices in the valve body end and into the corresponding engine combustion chamber. The nozzle valve is returned to its seat by pressure exerted by the spindle spring when the fuel injection pump has ceased to deliver fuel to the nozzle holder.

A certain amount of fuel seepage between the lapped surfaces of each nozzle valve and valve body is normal and necessary for lubrication. This fuel accumulates around the spindle and in the spring compartment of the fuel nozzle, and is returned through the fuel drip manifold and fuel return lines to the fuel tank.

2. Service

After each operating interval of approximately 2000 hours, the fuel injection nozzles should be removed, cleaned, tested, and adjusted if necessary. The specified opening ("popping") pressure is 2750 psi for the naturally aspirated engine and 2900 psi for the turbocharged engine. New production nozzles and rebuilt nozzles with new springs are set at 2800 to 2850 psi for the



1. Cap Nut
2. Gasket
3. Adjusting Screw
4. Locking Nut
5. Gasket
6. Spindle Spring
7. Spindle
8. Holder Body
9. Dowel Pins
10. Nozzle Assembly
11. Retaining Nut
12. Gasket

Figure 10. Nozzle Holder Assembly

naturally aspirated engine and at 3100 to 3150 psi for the turbocharged engine to compensate for initial set of new spindle springs. Popping pressure can be adjusted with the pressure adjusting screw. Turn the adjusting screw counterclockwise to decrease opening pressure and clockwise to increase opening pressure. A nozzle tester with an accurate pressure gauge must be used to observe the opening pressure spray pattern and general function of the nozzle.

3. Fuel Injection Nozzle Holder Removal

   a. Thoroughly clean fuel injection nozzles, lines, connectors, and surrounding area.

   b. Remove fuel drip manifold and disconnect lines from nozzle holder assemblies.

CAUTION: Do not bend lines when disconnecting. Cover all openings immediately to prevent entrance of dirt.

   c. Remove nuts and lockwashers securing nozzles to cylinder head.

   d. Remove nozzles from cylinder head by using two small pry bars, or by using a slide hammer with adaptor similar to that illustrated in Figure 11.

CAUTION: Use care when removing an injection nozzle to prevent striking nozzle tip against a hard object which could result in damage to the tip.

4. Testing and Adjusting Fuel Injection Nozzle Holder

   A nozzle tester similar to that illustrated in Figure 12 is required to properly test and adjust fuel injection nozzles.

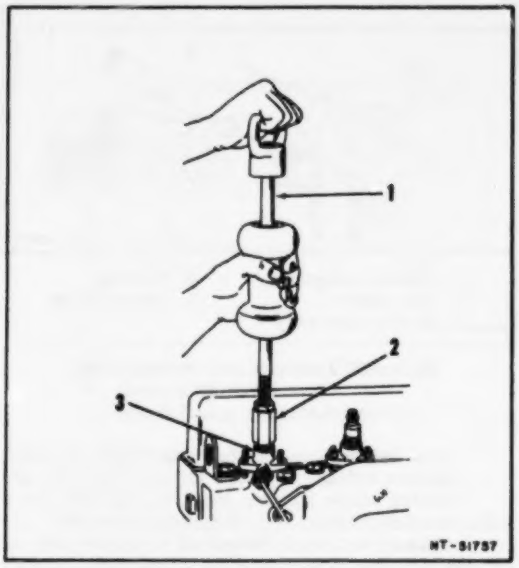
WARNING: Keep hands away from nozzle tip when popping a nozzle. The finely atomized fuel is ejected with sufficient force to penetrate the skin and cause blood poisoning.

   Test and adjust each fuel injection nozzle as follows:

   a. Bolt or clamp base of nozzle tester to a work bench.

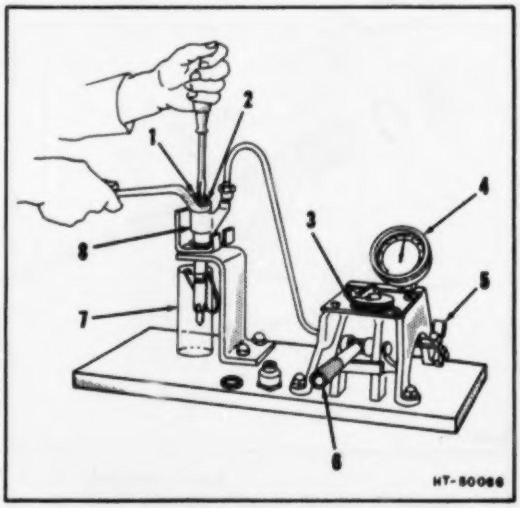
   b. Turn nozzle tester valve handle to the open position. Loosen filler cap to prevent air lock in the tester. Operate handle until fuel flows from end of tester fuel line, then close valve.

   c. Install nozzle in tester and connect line. Place spray collector under valve end of nozzle.



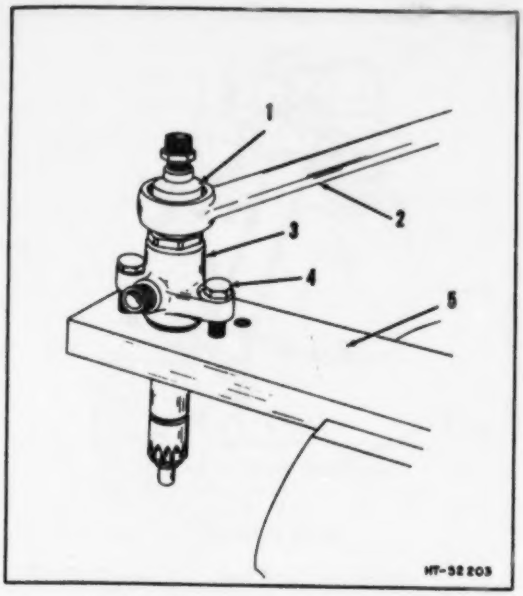
1. Slide Hammer
2. Adaptor
3. Nozzle Holder

Figure 11. Removing Fuel Injection Nozzle Holder



1. Pressure Adjusting Screw
2. Adjusting Screw Locknut
3. Filler Cap
4. Pressure Gauge
5. Valve Handle
6. Tester Handle
7. Spray Collector
8. Nozzle Holder Assembly

Figure 12. Fuel Injection Nozzle Tester

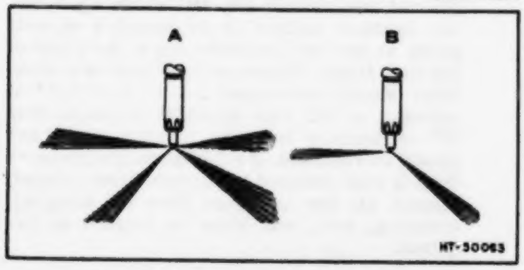


1. Cap Nut
2. Wrench
3. Nozzle Holder Assembly
4. Capscrew
5. Injection Nozzle Holding Fixture

Figure 13. Removing Nozzle Cap Nut

d. Open nozzle tester valve. Operate handle a few quick strokes and observe popping pressure indicated on pressure gauge. Specified popping pressure is 2750 psi for naturally aspirated engine and 2900 psi for the turbocharged engine.

NOTE: New production nozzles and rebuilt nozzles with new springs are set at 2800 to 2850 psi for the naturally aspirated engine and at 3100 to 3150 psi for the turbocharged engine to compensate for initial set of new spindle springs.



A. Acceptable spray pattern.
B. Non-acceptable spray pattern.

Figure 14. Nozzle Spray Patterns

e. Adjust fuel injection nozzle to obtain specified popping pressure as follows:

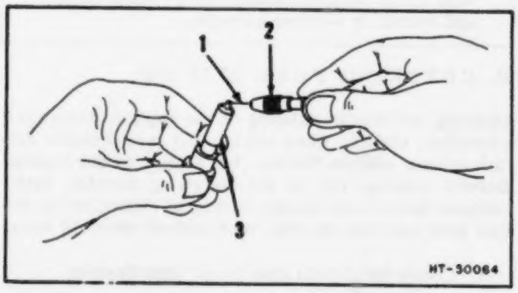
(1) Remove cap nut from upper end of nozzle and loosen adjusting screw locknut.

(2) While operating handle, turn pressure adjusting screw IN to increase or OUT to decrease popping pressure. When specified pressure is obtained, hold adjusting screw and tighten locknut to 75 to 90 lbs. ft. torque.

f. Dry the nozzle tip. Operate handle slowly until pressure is approximately 200 psi below popping pressure. Observe nozzle tip for fuel leakage. If nozzle does not leak, the nozzle valve is seating properly in the valve body. If drops of fuel collect at a pressure of approximately 200 psi, or less, below popping pressure, the nozzle valve is not seating properly. In this case, the valve body and valve must be removed for cleaning and inspection.

g. If the nozzle proved satisfactory when subjected to the leakage test above, operate handle at a speed of approximately 100 strokes per minute and observe nozzle spray pattern.

h. The nozzle tip has 4 equally spaced holes, 90° apart. Size and spacing of these holes determines the spray pattern. If fuel is discharged evenly through all 4 holes at specified popping pressure, the spray pattern is considered satisfactory. However, if fuel is not discharged evenly from all 4 holes, a plugged hole(s) is indicated, in which case, the nozzle must be removed and cleaned using a proper size cleaning wire. Refer to Paragraph D of Topic 2 and Paragraph C of Topic 8.



1. Cleaning Wire
2. Pin Vise
3. Valve Body

Figure 15. Cleaning Nozzle Orifices

5. Installation of Fuel Injection Nozzle Holder Assembly

   a. Thoroughly clean nozzle holder bores in cylinder head. When cleaning bores, make certain old nozzle holder gaskets are removed because new gaskets must be used when installing the nozzle holders. Make sure no small particles of carbon are in nozzle holder bores that could prevent nozzle holder gaskets from seating properly, thereby permitting "blow-by" from the cylinders.

   b. Place new holder gasket, concave face down, in position on nozzle holder. Carefully position nozzle holder in nozzle bore of cylinder head.

   c. Install nozzle holder washers and nuts for each nozzle but do not tighten at this time. Place fuel injection tubes in position in nozzle holders. Start injection tube nuts but do not tighten at this time. Install fuel drip manifold.

   d. Tighten nozzle holder nuts alternately to 9 to 12 lb. ft. torque. Tighten injection tube and fuel return manifold nuts securely.

   e. Start engine and observe fuel injection tubes and fuel return manifold connections for fuel leakage. Correct any leaks found.

G. REMOVING CARBON FROM FUEL INJECTION NOZZLE BORE

If the cylinder head has been removed from the engine, it is advisable to remove carbon deposits from nozzle bores with a tool similar to the one illustrated in Figure 16. Use a wire brush to remove carbon from nozzle tip holes in the cylinder head before reinstalling it on the engine.

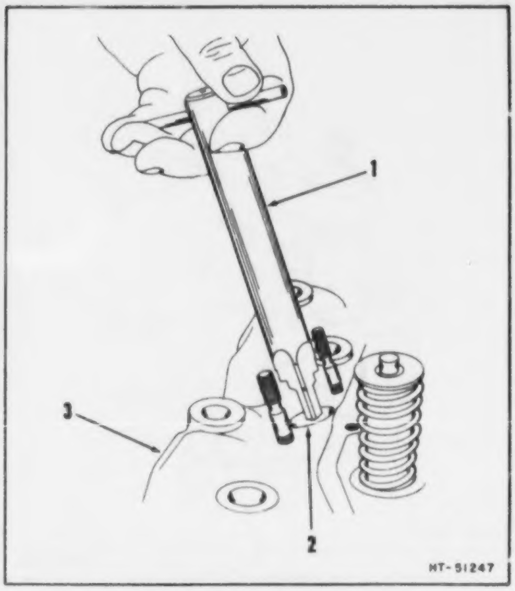
CAUTION: Under no circumstances should an engine be operated with a leaking or "blow-by" nozzle holder because localization of heat will occur that will distort the nozzle holder and result in serious damage.

H. CHECKING FUEL SYSTEM

Missing or uneven running of the engine, excessive vibration, stalling when idling, and loss of power are indications of insufficient fuel supply to the engine. Before making any of the following checks, make certain there is an ample supply of clean fuel in the fuel tank and that the fuel tank shutoff valve is open.

1. Check for Admission of Air Into System

   Remove fuel return line from fitting in the injection pump cover. Insert length of hose on the fitting. Place other end of hose in a container partially filled with fuel oil. Run engine at approximately 800 to 1000 rpm and observe end of hose in container for bubbles. Occasional bubbles are permissible, however, excessive bubbling or foaming indicates air is being drawn into the system. Correct this condition by tightening any loose low pressure fuel line connections and filter connections.



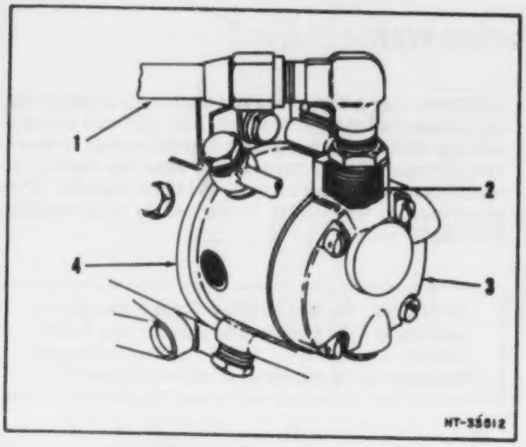
1. Carbon Removing Tool
2. Fuel Injection Nozzle Bore
3. Cylinder Head

Figure 16. Removing Carbon From Fuel Injection Nozzle Bore

2. Check for Clogged Fuel Filter and Clogged or Collapsed Fuel Lines

   A clogged filter or restriction(s) in fuel lines will cause loss of power, engine stalling, or erratic operation. A simple method of eliminating these troubles is to remove the fuel filter, blow out all low pressure fuel lines with filtered compressed air, and install a new filter. Another method is to install a vacuum gauge at the inlet and also one at the outlet of the fuel filter. Pressure drop across a clean filter should not exceed 1-1/2" to 2-1/2" of mercury at full load speed. A pressure drop 10" of mercury indicates filter is loaded and should be replaced. If a 10" mercury pressure drop is still obtained when a new filter is used, inspect all low pressure lines for clogging, crimping, etc., and clean or replace as required.

   To check high pressure lines between fuel pump and fuel injection nozzles, start engine and loosen each line nut, one at a time, at the injectors. If no fuel is observed at the loosened



1. Filter to Pump Inlet Line
2. Strainer
3. End Plate
4. Fuel Injection Pump

Figure 17. Fuel Strainer Location

line nut, line may be clogged, crimped, or cracked. In any case, it must be replaced.

Check fuel strainer in end plate of the injection pump. Remove foreign material if screen is clogged.

3. Check for Inoperative Fuel Transfer Pump

If engine is still erratic after making checks detailed in Steps 1 and 2 above, check operation of the fuel transfer pump and end plate pressure regulating valve. Run engine until normal operating temperature is reached, then shut it down. Remove plug marked OUT in bottom of end plate opposite fuel inlet, and install a pressure gauge. With key switch in OFF position and throttle in IDLE position, crank engine with the starter. Minimum pressure should be 6 psi at 150 rpm cranking speed. If pressure is less than 6 psi, check for malfunction in end plate and transfer pump parts.

4. Check for Inoperative Fuel Injection Nozzles

Missing or uneven running of engine and loss of power are also indicative of an inoperative fuel injection nozzle(s). To locate a faulty fuel nozzle, use following procedure:

a. Run engine at low idle speed and "cut out" each fuel nozzle in turn by loosening line nut attaching high pressure line to its corresponding fuel nozzle.

b. A decrease in engine speed with line nut loosened indicates fuel nozzle for that cylinder is functioning properly. If engine speed does not decrease, the fuel nozzle is inoperative and should be repaired or replaced.

5. Check for Inoperative Fuel Injection Pump

Do not replace the fuel injection pump before making a compression test. The compression test is used to detect burned or stuck valves, worn or scored pistons/sleeves, worn or stuck rings, etc., that cause faulty engine operation.

If all possible causes for insufficient fuel supply have been eliminated and the engine still runs unevenly, and normal engine performance is not obtained, the fuel injection pump may be at fault and should be checked, repaired or replaced. The faulty fuel injection pump (with governor) should be taken to your nearest Allis-Chalmers dealer for testing and repair.

IMPORTANT: Do not replace the fuel injection pump until making certain that all other possible causes for improper engine operation have been eliminated.

TOPIC 13. LUBRICATION SYSTEM

A. GENERAL

The engine is pressure lubricated throughout by a gear type lubricating oil pressure pump, driven by the oil pump driving gear in mesh with a gear at the center of the camshaft. The engine oil pressure should be between 30 and 55 psi when the engine is operating at full throttle and with the engine coolant at normal operating temperature.

The lubrication system is so designed that the engine can be operated at angles up to 15°.

B. GENERAL MAINTENANCE

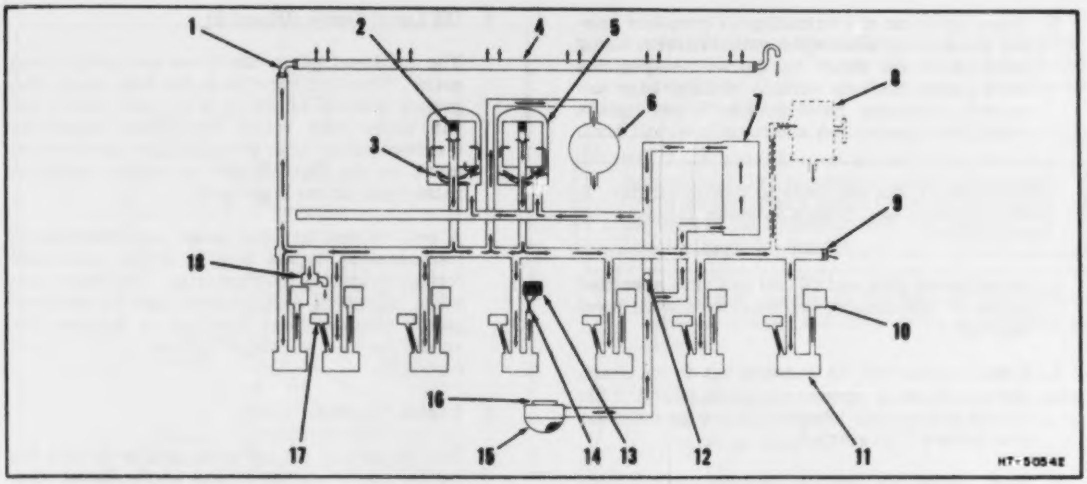
The level of the lubricating oil in the oil pan should be checked at the start of each period of engine operation before the engine is started. If the oil level is checked immediately after the engine is shut off, you will not get a true reading for it will register low on the dipstick. Add the specified lubricant as necessary to raise the oil level to the full mark on the oil level gauge (dipstick). Once the engine has started, observe the engine lubricating oil pressure indicated by the oil pressure gauge. If the engine is cold, no pressure may be indicated by the gauge for a few seconds after the engine starts, but if the pressure does not then rise to normal or above, the engine must be stopped immediately and the cause determined and corrected.

After starting a turbocharged engine, it is extremely important that it be allowed to idle for 3 to 5 minutes without racing. This permits lubricating oil to warm and circulate freely through the bearings before the turbocharger is operated at higher speeds. This procedure is especially important in cold weather starting.

CAUTION: Do not allow turbocharger to operate at high speeds with insufficient lubrication. Complete failure of turbocharger bearings in 30 seconds or less can result.

Before stopping engine, always allow it to operate at a fast idle for a minimum of 5 minutes. This procedure will allow the engine and equipment to cool gradually and uniformly. It will also allow turbocharger impeller speed to drop substantially before its supply of oil is cut off.

Maintenance personnel should familiarize themselves with recommended lubrication intervals and grades of oil specified for use in the engine. (Refer to preceding Topics 6 and 8.) Change oil and replace filter elements at operating intervals of 100 hours, or more often under adverse operating conditions.

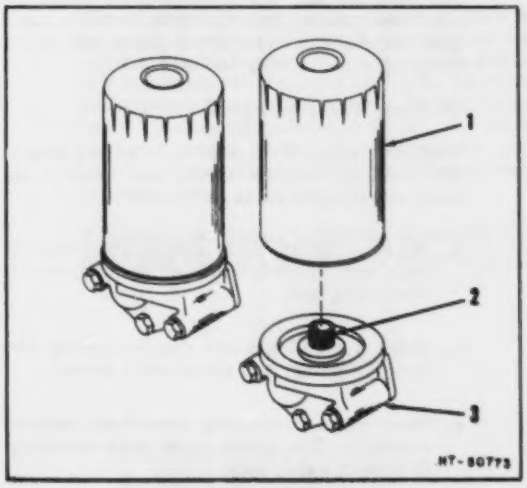


1. 1/16" Elbow Restrictor
2. Relief Valve
3. Drain Back-Check Valve
4. Rocker Arm Shaft
5. Lube Oil Filter
6. Turbocharger
7. Oil Cooler
8. Air Compressor (Optional)
9. 1/16" Restrictor
10. Cam Bearing
11. Main Bearing
12. Gallery Plug
13. Oil Pump Drive Gear
14. 3/32" Restriction
15. Oil Pump
16. Relief Valve (Dumps internally)
17. Rod Bearing
18. Oil Pressure Regulating Valve

Figure 2. Lubrication Oil Flow Schematic for Model 3500 Diesel Engine

C. LUBRICATING OIL FILTERS

Lubricating oil filters are the full flow, throw away type. They are screwed onto filter bases located on the right side of the engine near the flywheel housing. Each filter contains a check valve, a bypass valve, and an integral filter-to-base gasket. The check valve, located in the filter bottom, prevents oil from draining down into the oil pan when the engine is not in operation.



1. Filter (Disposable Type)
2. Filter Base Nipple
3. Base Assembly

Figure 3. Lubricating Oil Filters

A bypass valve in the filter top permits unfiltered oil to bypass the filter element and go directly to the main gallery if element becomes clogged, or if oil becomes too thick in cold weather to circulate freely through the element.

The oil pump forces oil through a passage into an annular cavity in the upper portion of the filter base assembly. The filter is positioned on the base with oil inlet openings directly over the annular cavity. Pressurized oil upsets the check valve and fills the area between element and shell. Oil is filtered as it passes through and into the hollow center area of the element. From the center area it flows down through the filter base center passage and into the main oil gallery of the cylinder block.

D. LUBRICATING OIL AND FILTER REPLACEMENT

1. Operate engine until coolant is at minimum operating temperature. Remove plug from either side of oil pan and let oil drain.

2. Thoroughly clean filters and surrounding area.

3. Unscrew filters and remove them from the base assemblies. Discard both filters.

4. Clean dirt and sediment from filter bases.

5. Apply light coat of lubricating oil to rubber gasket in bottom of both replacement filters. Using hand pressure, screw each filter into position until gasket contacts surface of filter base assembly. Continue hand pressure and tighten each filter a minimum additional one-half turn.

CAUTION: Do not use tools to tighten oil filters. Always use Allis-Chalmers replacement filters.

6. Install drain plug and fill oil pan with specified grade of lubricant to top mark on the oil level dipstick.
7. Crank engine for 15 seconds but do not start. This is done to assure complete filling of the filters and to pump lubricant to engine components before it is started.
8. Start engine and run for approximately 5 minutes.
9. Stop engine and allow several minutes for oil to drain back to the oil pan before checking level.
10. Check oil level with dipstick. Add oil as necessary to raise level to uppermost mark.
11. With engine running, check filters for leakage and make certain they are properly installed.

E. LUBRICATION SYSTEM MAINTENANCE

Proper maintenance of the lubrication system requires observance of the following checks and services:

1. Lubricating Oil

Lubricating oil must be of the best quality available and be of proper SAE weight for prevailing ambient temperature. (Refer to Topic 6.) Keep oil free of water and abrasives by proper handling and storage.

2. Daily Check

Before each period of operation, check oil level in the oil pan. If necessary, add oil to bring level to high mark on the oil level gauge. Inspect engine for evidence of oil leaks and make necessary repairs.

3. Cooling System Temperature

It is important that cooling system temperature be maintained at 180°F minimum, so lubricating oil will be hot enough for proper filtering. Low cooling system temperature will cause low oil temperature, and consequently, poor filtering of lubricating oil. This, in turn, will result in rapid wear of all moving parts.

4. Oil Level Gauge (Dipstick)

The oil level gauge has a low and a high level mark. When oil level is at the high mark, the proper amount of oil is in the pan. Never fill pan above high mark. The engine cannot be operated safely after level reaches the low level mark on the dipstick and oil must be added to raise level to the high mark.

A seal in the oil level gauge cap prevents oil from leaking to the outside of the engine and foreign material from entering. For these reasons, the gauge must be kept tight on the level gauge adaptor. Each time oil is changed, inspect the seal to make certain it is in good condition.

5. Engine Breather Tube

The purpose of the breather tube is to vent the inside of the engine to the atmosphere, thus preventing pressure buildup and removing harmful vapors from the crankcase, gear train, and valve compartment. If the tube becomes clogged, vapors are trapped within the engine, and pressure buildup will force oil past crankcase seals, dipstick, cylinder head gasket etc.

After each operating interval of 500 hours, remove breather tube from the cylinder head cover. Clean inside of tube with cleaning solvent, blow out with compressed air, and replace on engine.

6. Oil Pan and Oil Pump Suction Screen

After every 3000 hours of operation, remove and clean oil pan. Wash sludge from bottom of pan with cleaning solvent. Also, remove suction screen from end of oil pump and clean thoroughly in cleaning solvent.

7. Oil Pump Pressure Relief Valve

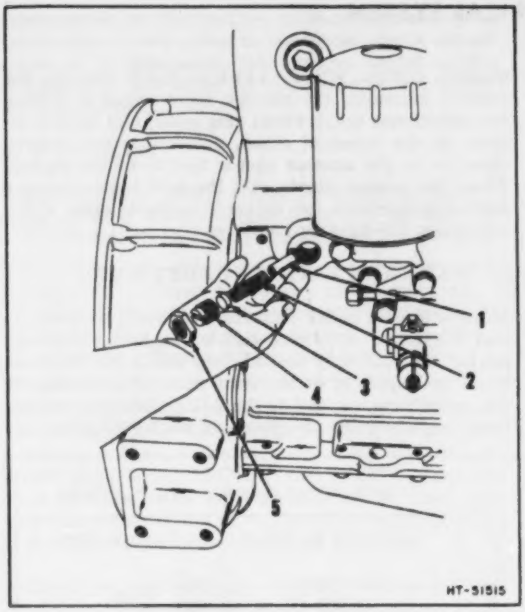
When the oil pan is removed for cleaning (every 3000 hours), remove, clean, and inspect oil pump relief valve parts as follows:

a. Depress relief valve spring and retainer with two screwdrivers or an improvised two-prong tool.

b. Drive out roll pin and remove spring retainer, spring, and relief valve piston.

c. Wash parts in cleaning solvent and inspect carefully. The piston must slide smoothly in bore of valve body.

d. If piston is scratched or shows signs of excessive wear, replace and install in bore of relief valve. The installation is a direct reversal of the removal procedure.



1. Piston
2. Spring
3. Spacer
4. Valve Adjusting Screw
5. Jam Nut

Figure 4. Oil Pressure Regulating Valve Details

8. Oil Pressure Regulating Valve

The oil pressure regulating valve is located in the main oil gallery at the right-rear side of the cylinder block. Function of the valve is to maintain stabilized oil pressure within the lubrication system. When oil pressure at the regulating valve exceeds approximately 50 psi, the valve piston is raised off the valve piston seat, and oil is bypassed directly from the cylinder block to the oil pan.

If lubrication system is allowed to sludge, the valve may not work properly. If it sticks in the open position, a sharp drop in engine oil pressure will occur. Conversely, if it sticks in the closed position, a sharp rise in engine oil pressure will occur.

NOTE: A gasket is not required between the regulating valve screw jam nut and the cylinder block because a nylon pellet is located in the side of the adjusting screw to prevent oil leakage past the threads.

After each operating interval of 3000 hours, remove, clean, and inspect the valve parts as follows:

a. Thoroughly clean the area around the cylinder block where the pressure regulating valve is located.

b. Loosen jam nut and remove regulating valve screw, noting number of turns required for removal.

c. Withdraw the spacer, spring, and piston.

d. Wash valve parts in cleaning solvent and inspect carefully for wear or damage. Replace any necessary parts.

e. Inspect the valve seat (insert) in the cylinder block and clean if necessary.

f. Thoroughly clean valve bore in cylinder block, lubricate valve piston with clean oil (piston must slide smoothly in bore of cylinder block), and install the regulating valve components.

NOTE: Turn valve screw into cylinder block the same number of turns required for removal.

g. Start engine and allow it to reach normal operating temperature. Adjust oil pressure regulating valve screw to obtain oil pressure of 45 to 50 psi at high idle engine speed, then tighten jam nut securely. No further adjustment should be necessary.

TOPIC 14. ELECTRICAL SYSTEM

A. GENERAL

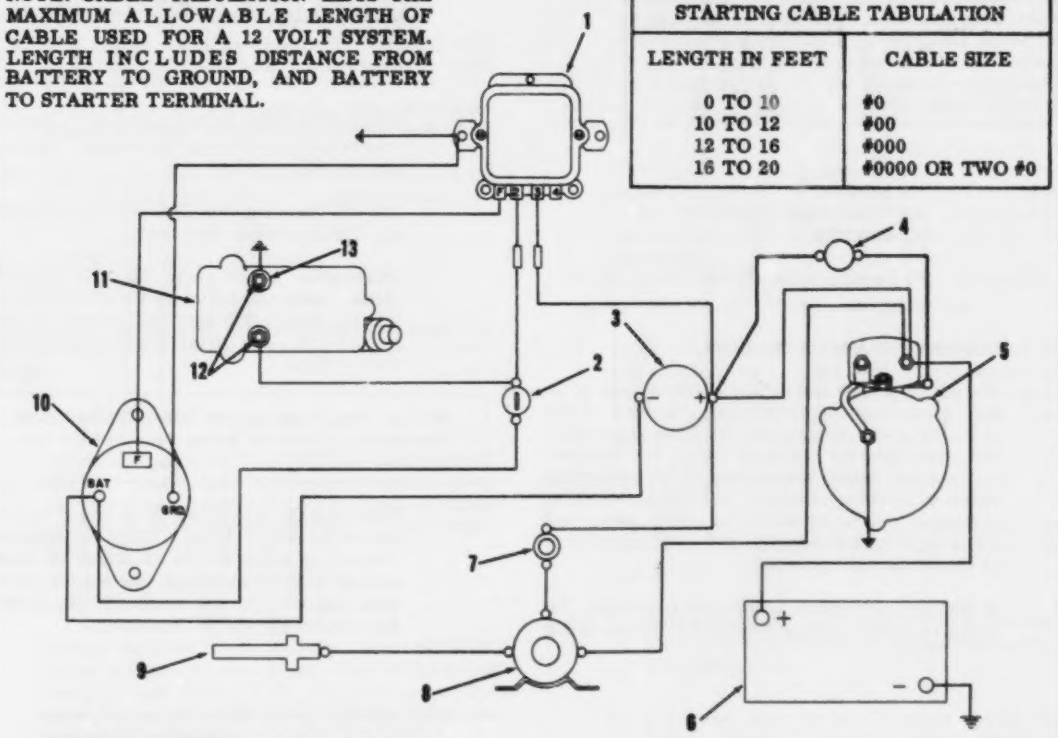
The electrical system includes the starter motor, alternator, fuel injection pump solenoid, voltage regulator, storage battery, ammeter, and air heater.

Basic components of the charging circuit include the battery, alternator, and voltage regulator. The 12 volt wet cell battery is the storage plant for electrical energy and must be kept fully charged. Electrical energy drained from the battery is replaced by the alternator. Excessive current flow can burn out the alternator and damage the battery to such an extent that it cannot hold a charge. A regulator connected into the circuit functions to prevent this.

The cranking circuit is composed of an electrical starting motor, a storage battery, and a push-button starter switch. When current flows through the starter solenoid, the starter drive pinion is shifted into mesh with the flywheel ring gear, and main contacts in the solenoid close, connecting the battery directly to the starter motor that turns the engine. When the engine starts and the push button starter switch is released, the solenoid contacts open, automatically disengaging the drive pinion.

B. WARRANTY AND ADJUSTMENT

Manufacturers of the batteries, starter, alternator, and regulator are responsible for this equipment during the warranty period. Any claim for replacement or repair of these items must be presented to the manufacturer, not to the Allis-Chalmers Manufacturing Company. Suppliers of such equipment are



NOTE: CABLE TABULATION LISTS THE MAXIMUM ALLOWABLE LENGTH OF CABLE USED FOR A 12 VOLT SYSTEM. LENGTH INCLUDES DISTANCE FROM BATTERY TO GROUND, AND BATTERY TO STARTER TERMINAL.

STARTING CABLE TABULATION

LENGTH IN FEET	CABLE SIZE
0 TO 10	#0
10 TO 12	#00
12 TO 16	#000
16 TO 20	#0000 OR TWO #0

NOTE: ALL ENGINE GROUNDS SHOULD HAVE A GOOD METALLIC CONTACT.

1. Voltage Regulator
2. Key Switch
3. Ammeter
4. Starter Button
5. Electric Starting Motor
6. Battery
7. Air Heater Button
8. Air Heater Solenoid
9. Air Heater Element
10. Alternator
11. Fuel Injection Pump
12. Fuel Injection Pump Solenoid Terminals
13. Ground Washer

Figure 1. Wiring Diagram - 12 Volt System

represented by distributors or dealers in nearly all cities who are authorized to make reasonable adjustments or replacements. Always give serial number of the engine and date it was delivered when presenting a claim of this nature.

C. BATTERY

If liquid level of battery is low, add distilled water to bring level of each cell to bottom of filler hole. Be sure filler plugs are tight and plug vents are open.

> CAUTION: Never fill battery after operation in below freezing weather because water will not mix with acid and may freeze. Always fill batteries before putting engine into service.

Periodically check external condition of battery and connecting cables. Keep batteries clean and secured. If battery is dirty, clean with soda solution and brush. Filler plugs should be tight to prevent any solution from entering cells. After foaming stops, flush surface with clean water and apply a thin coat of vaseline to posts and cable terminals.

Maintain battery in a fully charged condition. Check charge condition or specific gravity with a hydrometer with electrolyte temperature at 80° F.

Hydrometer Indication	Charge Condition
1.110 to 1.135	Completely discharged
1.170 to 1.200	One-fourth charged
1.205 to 1.230	One-half charged
1.235 to 1.260	Three-fourths charged
1.265 to 1.290	Fully charged

> CAUTION: Polarity of the electrical system is such that the negative battery terminal must be grounded. Make sure all grounding points have a metallic contact. When connecting either a trickle or fast type charger to the battery, it is imperative that correct polarity be observed. That is, connect the positive lead of the charger to the positive battery post and the negative lead to the negative battery post. Observe the same polarity rule when connecting booster batteries to the engine. When any work is performed on the electrical charging system, disconnect the battery to prevent short circuits.

D. ELECTRIC STARTING MOTOR

1. General

The starting motor is a heavy duty, 12 volt, overrunning clutch type unit. A solenoid switch, which is an integral part of the starting motor, is connected by linkage and a shift lever to a clutch in the starting motor nose housing. Closing of the starter switch completes the electrical circuit between storage battery and solenoid. The solenoid shifts the starter pinion gear into mesh with the engine flywheel ring gear and holds it in mesh during engine cranking.

> CAUTION: Do not operate cranking motor continuously for more than 30 seconds without pausing to allow it to cool for at least 2 minutes. Failure to observe this rule can result in overheating and failure of the motor.

2. Starter Removal and Installation

a. Disconnect battery cables and electrical lead wires from starter.

b. Remove capscrews and lockwashers that attach starter to flywheel housing. Remove starter and starter adaptor.

c. Install starter motor on engine by a direct reversal of the removal procedure. Connect cables and wires to starter.

3. Service

a. During startup, note starting motor action. The starter pinion gear should mesh promptly with the flywheel ring gear and spin the engine. After engine starts and motor switch opens, the starting motor should stop operating.

b. If starting motor cranks engine slowly or not at all, check the equipment. Failure to crank is normally caused by low battery charge, defective battery cables, poor connections in starting motor to battery circuit, defective starting motor, low temperatures, or various conditions in the engine.

c. Periodically check condition of battery, battery cables and connections, starting motor, solenoid switch, commutator, brushes, lead connections, and mounting.

d. Starter motor bearings are lubricated only when unit is disassembled for inspection or repair.

e. Brushes must make good contact with the commutator. Minimum tension of brushes is 80 ounces.

f. Check length of brushes. Original brush length is 3/4". They should be replaced if wear has decreased their length to 5/16" or less.

g. If commutator is dirty, clean with #00 sandpaper.

> CAUTION: Do not clean commutator with emery cloth. Emery is a conductor and can cause electrical shorts.

E. ALTERNATOR

1. General

The alternator is a continuous output, diode rectified unit, designed and constructed to provide extra long periods of reliable service with minimum maintenance. Two brushes carry current through two slip rings to the field coil of the rotor. The rotor is mounted on ball bearings at the drive end and on roller bearings at the slip ring end. A grease supply for each set of bearings eliminates need for periodic lubrication.

The stator windings are assembled inside a laminated core that forms part of the alternator frame. Mounted in the slip ring end frame are 6 rectifier diodes that are connected to the stator windings. These diodes replace the separately mounted rectifier that is used in other types of applications. They change AC voltage to a DC voltage that appears at the alternator BAT terminal.

CAUTION: Alternator ground polarity and battery ground polarity must be the same before making any connections. Instant damage to wiring and diodes will result if polarities are mismatched. Do not operate without a battery. Do not attempt to polarize alternator. Do not short across or ground alternator terminals. Never operate the alternator on an open circuit. Make absolutely certain all connections in the circuit are secure.

2. Alternator Removal

a. Remove capscrew attaching alternator to alternator adjusting brace.

b. Remove drive belts.

c. Mark alternator lead wires for subsequent identification. Disconnect lead wires.

d. Remove capscrews attaching alternator to the alternator mounting bracket. Remove alternator.

e. Install alternator in reverse order of removal.

3. Service

a. Check drive belts for alignment, tension, and wear. Refer to Topic 11.

b. Check for loose alternator mounting capscrews. Check for loose drive pulley.

c. Check terminals for corrosion and loose connections. Check wiring for frayed insulation.

d. Remove 4 bolts that secure slip ring end frame to drive end frame. Remove slip ring end frame from drive end frame.

NOTE: If brushes come in contact with shaft lubricant, thoroughly clean them with a soft dry cloth. Also clean shaft before reassembly.

e. Measure brush length. Original length is 1/2". If brushes are worn down 0.400", which is the effective brush wear length, they must be replaced.

f. Visually inspect brush springs for discoloration, corrosion, distortion, or other damage. If there is any doubt as to the condition of the brush springs, they should be replaced.

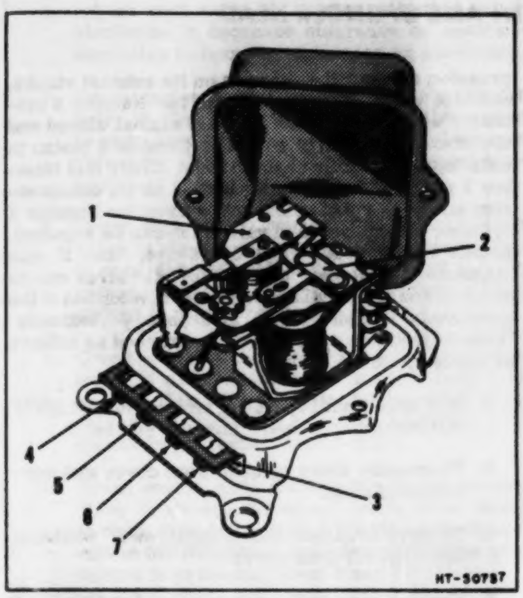
g. Check surface of slip rings. If surface is smooth but covered with a carbon-oil-dirt mixture, clean with 400 grain or finer polishing cloth. Spin rotor in a lathe, or other suitable device, and hold polishing cloth against slip rings until they are clean.

CAUTION: Cleaning slip rings without spinning the rotor may result in flat spots on the rings, causing brush noise.

h. If slip rings are too rough or are out of round, they must be turned in a lathe to within a 0.002" maximum indicator reading. Remove only sufficient material to make rings smooth and round. Finish with 400 grain or finer polishing cloth and blow away all dust.

i. The grease reservoir provides an adequate supply of lubricant for long periods of operation. When alternator is disassembled for overhaul or repair, fill the grease reservoir in each end frame with Delco-Remy grease, Part No. 1948791 to one-quarter full.

CAUTION: Do not overfill as this will cause bearings to overheat.



1. Field Relay Unit
2. Voltage Regulator Unit
3. Latch
4. F Terminal
5. No. 2 Terminal
6. No. 3 Terminal
7. No. 4 Terminal

Figure 2. Two Unit Voltage Regulator

F. VOLTAGE REGULATOR

1. General

The voltage regulator is a two unit regulator consisting of a voltage regulator unit and field relay unit. The voltage regulator unit operates to limit alternator voltage to a pre-set value, whereas the field relay unit connects the alternator field winding and regulator winding directly to the battery.

The two unit regulator has 4 slip connection type terminals. A projection on the connector body serves to latch the assembly together and prevent disconnections due to vibration. The assembly can be disconnected by lifting slightly on the latch.

CAUTION: Polarities of the regulator, alternator, and battery must be the same. Instant damage will result if polarities are mismatched. Do not short across or ground regulator terminals. Do not operate without a battery.

2. Voltage Regulator Removal

a. Mark regulator lead wires for subsequent identification. Disconnect lead wires.

b. Remove attaching capscrews, nuts, and lockwashers and remove regulator.

c. Install voltage regulator in reverse order of removal.

3. Service

Do not clean voltage regulator contacts unless performance indicates cleaning is necessary. A sooty or discolored appearance of contacts is normal after a relatively short period of operation and is not an indication that cleaning is necessary. However, if the voltage fluctuates, as evidenced by an unsteady voltmeter indication, contacts may have excessive resistance or be sticking and therefore, should be cleaned.

CAUTION: Before cleaning, make sure fluctuating voltage is not caused by loose connections or high resistance elsewhere in the system.

Contacts of the voltage regulator unit are made of soft material and must not be cleaned with a file. A strip of No. 400 silicon carbide paper, or equivalent, folded over and then pulled back and forth between the contacts is recommended as a satisfactory method of cleaning. After cleaning, wash contacts with trichlorethylene or alcohol to remove any residue. If voltage control has not improved, repeat cleaning and washing process.

Clean field relay contacts with a thin, fine-cut, flat file. Never use emery cloth or sandpaper. Remove only sufficient material to clean.

G. INTAKE AIR HEATER

If the engine does not start with the aid of the intake air heater, it is advisable to stop cranking the engine and inspect the heater circuit for the following causes of failure.

1. Open Electrical Circuit

Check all electrical connections for the operation of the heater and make certain the connections are tight. Make sure all cables are in good condition; wrap any frayed spots in the insulation with friction tape or replace cables. Check operation of heater element solenoid.

2. Heating Element Broken or Burned Out

On a naturally aspirated engine, remove air cleaner from intake manifold flange, or on a turbocharged engine remove the turbocharger outlet elbow with the air heater intact and ground the turbocharger outlet elbow. Press heater button and observe if the element becomes hot; visually inspect element for a broken or burned out element wire. Replace heating element if necessary.

3. Inoperative Heater Button

If the malfunction of the air heater was not due to a broken or burned out heating element, check heater button with a jumper cable to see if it is inoperative. Replace if necessary.

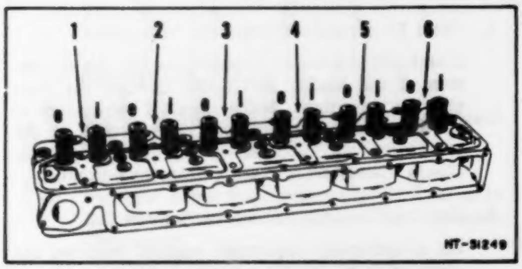
TOPIC 15. VALVE ADJUSTMENT AND CYLINDER HEAD

A1. VALVE LASH ADJUSTMENT

Correct clearance (valve lash) between end of intake valve stem, exhaust valve stem, and related rocker arms, is very important in diesel engine performance because of high compression developed within the cylinders. Insufficient valve lash will cause loss of compression, misfiring, and eventually lead to burning of valves and valve seats. Excessive valve lash will result in faulty engine operation, valve lifter noise, and cause rapid wear on the valve operating mechanism. With engine at normal operating temperature or 160°F minimum, specified valve lash for both intake and exhaust valves is 0.015". After any mechanical work has been done that may have disturbed the valve lash adjustment, set valves "cold" at 0.018" clearance so engine can be run and allowed to warm to normal operating temperature. After engine has warmed up to normal operating temperature, check valve lash again for proper clearance.

> CAUTION: After any mechanical work has been done that may have disturbed the valve lash adjustment, make certain the rocker arm adjusting screws are turned upward (counterclockwise) high enough to prevent rocker arms and push rods from opening too far. If rocker arms and push rods open too far, the pistons will strike the valves when the engine is cranked.

Valve lash must be adjusted when the piston is near top dead center on its compression stroke and intake and exhaust valves are closed. Number 1 and Number 6 pistons move up and down in their respective cylinders simultaneously. When one piston is on its compression stroke, the other is on its exhaust stroke, and vice versa. Observe valves for Number 6 cylinder; when the exhaust valve is almost closed and the intake valve starts to open, Number 6 piston is near top dead center on its exhaust stroke and Number 1 piston is in the same position on its compression stroke. At this point, both valves for Number 1 cylinder are closed and valve lash can be adjusted. Engine firing order is 1-5-3-6-2-4, and if this sequence is followed, the lash for all valves can be checked and adjusted in 2 complete revolutions of the crankshaft. Check valve clearance periodically. When adjustment is necessary, proceed as follows to obtain specified clearance:



1. No. 1 Cylinder
   e. Exhaust Valve
   i. Intake Valve
2. No. 2 Cylinder
   e. Exhaust Valve
   i. Intake Valve
3. No. 3 Cylinder
   e. Exhaust Valve
   i. Intake Valve
4. No. 4 Cylinder
   e. Exhaust Valve
   i. Intake Valve
5. No. 5 Cylinder
   e. Exhaust Valve
   i. Intake Valve
6. No. 6 Cylinder
   e. Exhaust Valve
   i. Intake Valve

Figure 1. Valve Locations

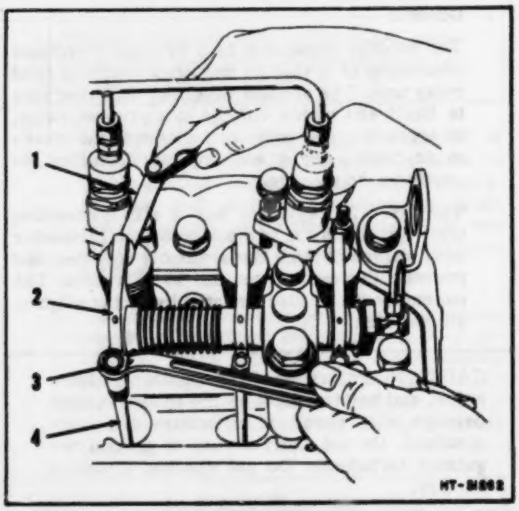
1. Run engine until operating temperature of 160°F minimum is reached. Stop the engine.

2. Thoroughly clean cylinder head cover and surrounding area.

3. Remove breather tube, capscrews, washers, and cylinder head cover.

4. Crank engine until exhaust valve for Number 6 cylinder is almost closed and intake valve starts to open, then check and adjust intake and exhaust valve lash for Number 1 cylinder.

5. Use a 0.015" feeler gauge and check clearance between valve stems and rocker arms. Gauge should pass between rocker arm and corresponding valve stem with a slight drag when valve lash is properly adjusted.



1. Feeler Gauge
2. Rocker Arm
3. Adjusting Screw
4. Push Rod

Figure 2. Adjusting Valve Lash

6. Adjust each valve by turning adjusting screw clockwise to decrease clearance or counterclockwise to increase clearance as necessary.

7. Crank engine until Number 2 cylinder exhaust valve is almost closed and intake valve starts to open, then adjust lash for intake and exhaust valves for Number 5 cylinder, following procedure in preceding Steps 5 and 6.

8. Crank engine until Number 4 cylinder exhaust valve is almost closed and intake valve starts to open, then adjust lash for intake and exhaust valves for Number 3 cylinder, following procedure in preceding Steps 5 and 6.

9. Crank engine until Number 1 cylinder exhaust valve is almost closed and intake valve starts to open, then adjust lash for intake and exhaust valves for Number 6 cylinder, following procedure in preceding Steps 5 and 6.

10. Crank engine until Number 5 cylinder exhaust valve is almost closed and intake valve starts to open, then adjust lash for intake and exhaust valves for Number 2 cylinder, following procedure in preceding Steps 5 and 6.

11. Crank engine until Number 3 cylinder exhaust valve is almost closed and intake valve starts to open, then adjust lash for intake and exhaust valves for Number 4 cylinder, following procedure in preceding Steps 5 and 6.

B. TORQUING CYLINDER HEAD

If the cylinder head is removed for any reason, such as repair, overhaul, etc., the cylinder head capscrews must be tightened evenly and in the sequence illustrated in Figure 3. A new cylinder head gasket must be used when installing the cylinder head. Make certain the gasket is installed with the indicated side down. Install cylinder head as follows:

1. Thoroughly clean top deck of cylinder block and under-side of cylinder head.

2. Check for specified 0.002" to 0.005" cylinder sleeve protrusion above top deck of block. Correct, if necessary, by reconditioning sleeve seat in block with recommended tool and installing sleeve shims under sleeve flange to obtain 0.002" to 0.005" protrusion.

3. Install new gasket on cylinder block with indicated side down as stamped on gasket. Follow instructions packaged with service cylinder head gasket. Do not use sealer or gasket dope. The gasket as supplied has been pre-coated with phenolic sealer and an anti-stick compound.

4. Install cylinder head. Lubricate threads of 20 short cylinder head capscrews with light coat of engine lubricating oil and install in cylinder head. Tighten capscrews to 90 to 110 lbs. ft. torque following sequence depicted in Figure 3, Section A.

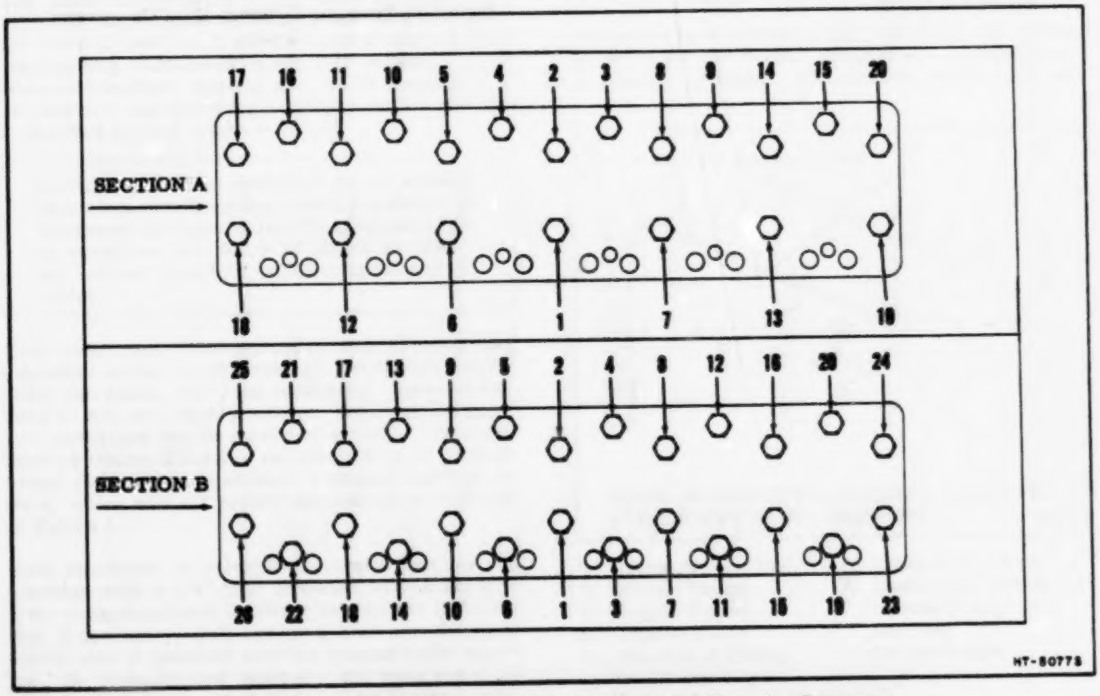


Figure 3. Cylinder Head Capscrew Locations and Torquing Sequence

CAUTION: Torque figures in this and following steps are based on engine oil lubricated threads. To prevent overstressing of capscrews, do not use extreme pressure lubricants of any kind.

5. Lubricate threads of 6 long capscrews with light coat of engine lubricating oil. Install rocker arm shaft and bracket assembly. Starting at center of head and working alternately toward each end, tighten capscrews to 90 to 100 lb-ft torque.

6. Tighten all 26 capscrews to 130 to 140 lb-ft torque following sequence depicted in Figure 3, Section B.

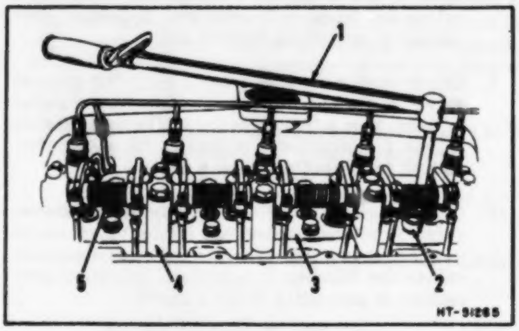
NOTE: A cylinder head wrench equivalent to "Snap-On" S-8684 is required for tightening capscrews under the rocker arm shaft.

7. Retighten all 26 capscrews to 130 to 140 lb-ft torque following sequence depicted in Figure 3, Section B.

8. Lubricate threads of six 3/8" capscrews with light coat of engine lubricating oil. Install capscrews in rocker arm brackets and tighten to 28 to 33 lb-ft torque. Adjust all intake and exhaust valves to cold tappet clearance of 0.018". Run engine for approximately 1 hour, preferably under load, with minimum water temperature of 160°F.

9. Retighten all 26 capscrews to 130 to 140 lb-ft torque, following sequence depicted in Figure 3, Section B. If capscrew does not move when this specified torque is reached, back it off slightly by loosening, then retighten to specified torque. This is important in eliminating possible false torque readings due to temporary thread seizure.

10. Adjust clearance of tappets to 0.015", hot. Refer to preceding Paragraph A.



1. Torque Wrench
2. Cylinder Head Wrench
3. Cylinder Head
4. Rocker Arm Shaft Bracket
5. Rocker Arm Shaft

Figure 4. Torquing Cylinder Head Capscrews

TOPIC 16. INTAKE AND EXHAUST SYSTEMS

A. GENERAL

The intake and exhaust system consists of those components that convey filtered air to engine cylinders and exhaust gases to the atmosphere. The intake system consists of intake valves, intake manifold, and air cleaner. The exhaust system consists of exhaust valves, exhaust manifold, muffler, and exhaust piping extensions. If engine is equipped with a turbocharger, its compressor side is part of the intake system and its turbine side is part of the exhaust system.

It is important that an ample supply of fresh clean air be provided to the combustion chambers. Insufficient air will limit amount of fuel the engine can burn and lead to loss of power, excessive exhaust smoke, high fuel consumption, and eventually to engine failure.

In warm weather, sufficient heat is generated by compression of air within the cylinders to ignite the fuel and start the engine within a very short cranking period. However, in cold weather, the "drag" caused by cold oil between pistons and cylinder walls and in the bearings, reduces cranking speed of the engine. A large part of the heat generated by compression of air is absorbed by the cold pistons and cylinder walls. This heat loss and reduced cranking speed may lower temperature of air in the cylinders to a point too low to ignite the fuel. In this case an intake air heater is used, or in extreme cold weather engine starting may be assisted by use of an optional equipment cold weather starting aid, which consists of a pressurized can containing a highly volatile fluid that is injected into the intake manifold.

CAUTION: Muffler installations or exhaust pipe extensions from the manifold outlet must be adequately supported and flexibly connected to eliminate possibility of strain on either the exhaust manifold outlet or turbocharger outlet.

Total restriction of the exhaust system of a naturally aspirated engine at the exhaust outlet with engine under full speed, full load conditions, must not exceed 3" mercury back-pressure. Total restriction of a turbocharged engine must not exceed 1" mercury back-pressure. If there is any question as to whether or not the engine has excessive exhaust back-pressure, check with a mercury manometer as depicted in Figure 1.

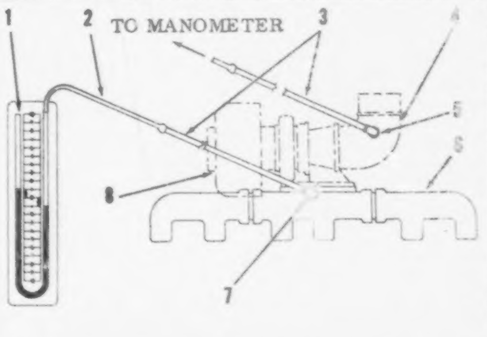
Most manifolds on naturally aspirated engines are provided with a 1/4" pipe threaded hole in the side of the exhaust outlet to facilitate manometer installation. If necessary, drill and tap a 1/4" pipe threaded hole in side of manifold near the exhaust outlet opening. On turbocharged engines, the manometer is connected to the exhaust elbow. (See Figure 1.) To connect manometer to exhaust manifold, screw a 1/4" X 1/8" reducer bushing into hole in side of manifold. Fitting must be flush with inside and perpendicular to manifold to avoid false readings. Fasten about 3 feet of 1/4" OD copper tubing to fitting in manifold. From other end of copper tubing connect a length of rubber tubing to one side of the manometer.

It should be noted in the illustration, Figure 1, that the manometer scale is graduated in inches both above and below the 0 mark, and each inch is divided into tenths. When manometer is set up for use, sufficient mercury must be put in the U-shaped tube so height in both columns aligns with 0 line on the scale.

Take exhaust back-pressure readings when engine is developing its maximum horsepower and rpm. When reading manometer, add height of liquid in both columns to obtain final figure. For example, if liquid is 1.5" high in left column and 1.5" low in right column, the manometer indicates 3" mercury back-pressure.

NOTE: If mercury is 1.5" high in right column and 1.5" low in left column, the manometer indicates 3" mercury vacuum, rather than pressure. A 1" mercury indication is equivalent to 0.491 after psi, 3" of mercury is equal to 3 X 0.491 or 1.473 psi. If a manometer is not available, an accurate pressure gauge can be used.

Excessive back-pressure will result in poor engine performance and shortened engine life. Measurement of exhaust pressure will indicate whether or not



NOTE: MANOMETER AS SHOWN INDICATES 2" MERCURY BACK-PRESSURE.

1. U-tube Manometer
2. Rubber Tubing
3. Copper Tubing
4. Exhaust Elbow
5. Location of Fitting for Turbocharged Engines
6. Exhaust Manifold
7. Location of Fitting for Naturally Aspirated Engines
8. Turbocharger

Figure 1. Checking Exhaust Back-Pressure

capacity of exhaust system is adequate. If back-pressure reading is higher than the specified figure, one or more of the following factors is the cause:

1. Sharp right angles or excessive bends in exhaust piping. All angles and bends must be gentle sweeping curves. Piping should have as few angles/bends as possible.
2. Exhaust piping diameter too small. Pipe size must never be less than diameter of exhaust outlet opening. As piping length increases, so should the diameter.
3. Foreign material causing restrictions in muffler or piping.
4. Inadequate muffler capacity.

B. MANIFOLD MAINTENANCE

1. Use new gaskets when reinstalling manifolds.
2. Periodically check all manifold mounting capscrews and clamps for tightness after engine is hot. Tighten manifold mounting capscrews to specified torque, starting at the center and working alternately toward each end.
3. At time of overhaul, check manifold for carbon deposits. Clean and remove obstructions found within the manifold.
4. If manifold is cracked, repair or replace as necessary.
5. If mounting surfaces of one section are warped and will not seal, it must be replaced or re-machined. If material is machined from one section, a like amount must be removed from the other 2 sections.

TOPIC 17. AIR CLEANER

A. GENERAL

The purpose of the air cleaner is to remove dust and other foreign material from air used by the engine. Engine life depends largely on efficiency of the air cleaner. Rapid wear on cylinder sleeves, pistons, and rings will result if it is not kept in good condition and properly serviced.

Light duty, heavy duty, and extra heavy duty air cleaners are available for this series of engines. Frequency of servicing required, regardless of air cleaner used, depends on amount of foreign material in air surrounding working location of the engine.

All dry type air cleaners are equipped with a filter service indicator. Service the filter when so indicated. However, if a service indicator is not utilized, a cartridge renewal period should be determined by daily inspection of the air cleaner under actual operating conditions, until the period can be established.

Automatic self-cleaning of the pre-cleaner (Farr extra heavy duty air cleaner) is achieved by the use of an aspirator in the exhaust system. Air enters the pre-cleaner and is spun to remove 90% of dust particles. The separated dust falls into the dust bin and is drawn out thru the aspirator. Pre-cleaned air then enters the filter cartridge for second-stage cleaning. The aspirator is connected to the pre-cleaner panel by means of a metal flexible hose.

Inspect air cleaner body periodically for dents, cracks, etc. Also check for damaged gaskets and hoses, loose hose clamps, and for leaks that allow air to enter engine without first passing through the filter element. Correct any such condition found by immediate repair or replacement of faulty parts.

NOTE: Always refer to instructions on air cleaner.

B. SERVICE

1. Not applicable.

Figure 1. Not applicable.

Figure 2. Not applicable.

Paragraph 2. Not applicable.

Paragraph 3. Not applicable.

1.17
Page 2 Not applicable.

Figure 3. Not applicable.

Figure 4. Not applicable.

Figure 5. Not applicable.

1.17
Page 3 Not applicable.

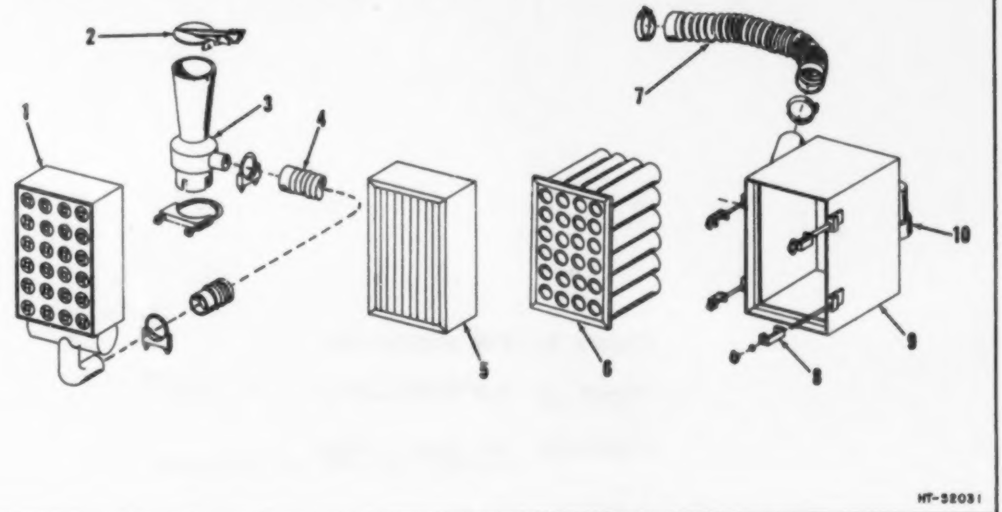
Figure 6. Not applicable.

Figure 7. Not applicable.

Figure 8. Not applicable.

1.17
Page 4 Not applicable.

HEAVY DUTY AIR CLEANER CONSISTS OF ITEMS 5, 6, 7, 8, 9, AND 10. EXTRA HEAVY DUTY AIR CLEANER CONSISTS OF ALL ITEMS ILLUSTRATED EXCEPT ITEM 5.



1. Precleaner Panel
2. Aspirator Rain Cap
3. Aspirator
4. Hose, Precleaner to Aspirator
5. Moisture Eliminator
6. Filter Element
7. Hose, Air Cleaner
8. Clamp
9. Housing Assembly
10. Service Indicator

Figure 9. Farr Dry Type Air Cleaners - Heavy Duty and Extra Heavy Duty

4. Farr Air Cleaner - Heavy Duty Dry Type

   a. Loosen clamps attached to air cleaner housing (Figure 9) and remove the moisture eliminator.

   b. Carefully remove dirty air cleaner element from housing and discard it.

CAUTION: Do not clean or re-use dirty air cleaner element.

   c. Remove all foreign material from inside of housing. Inspect housing for damage, leaks, etc.

   d. Clean moisture eliminator panel.

   e. Install new element in air cleaner housing. Make certain sealing flange is properly positioned and seated.

CAUTION: Inspect element for damage before installation.

   f. Install moisture eliminator panel.

   g. Tighten wing nuts to 5 lb-ft torque. If a torque wrench is not available, tighten each wing nut finger tight, then tighten each one an additional 1-1/2 turns using a suitable tool. Do not tighten nuts in direct sequence, but in a diagonal sequence to assure a uniform seating procedure.

NOTE: If, at a later date, inspection of wing nuts indicates that they are at less than 5 lb-ft torque; this is due to a slight set in plastic face of the element and does not impair seal between element and housing. Re-tightening of wing nuts is not recommended unless they are loose, as this may break the seal that has been formed.

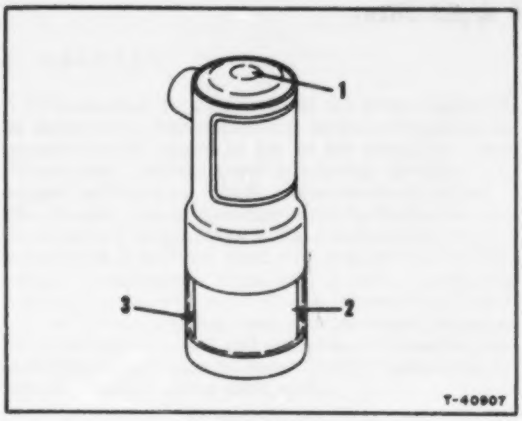
   h. Reset service indicator by pressing reset button on top of indicator.

5. Farr Air Cleaner - Extra Heavy Duty Dry Type

   a. Loosen clamps attached to air cleaner housing.

   b. Loosen hose clamp securing flexible hose to pre-cleaner pan elbow. Remove pre-cleaner.

NOTE: Dust particles are removed from the pre-cleaner by action of the aspirator, therefore, the pre-cleaner requires no service.



1. Reset Button
2. Red Signal
3. Window

Figure 10. Air Filter Service Indicator

c. Carefully remove dirty air cleaner element from housing and discard it.

CAUTION: Do not clean or re-use dirty air cleaner element.

d. Remove all foreign material from inside of housing. Inspect housing for damage, leaks, etc.

e. Install new element in air cleaner housing. Make certain sealing flange is properly positioned and seated.

CAUTION: Inspect element for damage before installation.

f. Install pre-cleaner on housing. Insert flexible hose on pre-cleaner connection and tighten hose clamp.

g. Secure pre-cleaner with clamps attached to housing. Tighten wing nuts to 5 lb-ft torque. If a torque wrench is not available, tighten each wing nut finger tight, then tighten each one an additional 1-1/2 turns using a suitable tool. Do not tighten nuts in direct sequence, but in a diagonal sequence to assure a uniform seating procedure.

NOTE: If, at a later date, inspection of wing nuts indicates that they are at less than 5 lb-ft torque; this is due to a slight set in plastic face of the element and does not impair seal between element and housing. Re-tightening of wing nuts is not recommended unless they are loose, as this may break the seal that has been formed.

h. Reset service indicator by pressing reset button on top of indicator.

C. AIR FILTER SERVICE INDICATOR

Purpose of the service indicator, which is factory set, is to provide a visual signal when the air cleaner is in need of servicing. Dirt trapped by the air cleaner gradually reduces volume of air flow through the filter and increases the air cleaner-to-engine pressure drop. As pressure flow decreases, the red signal of the filter indicator gradually rises in the window and when fully exposed is locked in this position. At this time the air cleaner should be serviced or the element replaced or serviced. After servicing, reset signal by pressing reset button located on top of indicator.

NOTE: Observing the indicator when the engine is running will indicate the degree of filter element contamination.

TOPIC 18. Not applicable.

TOPIC 19. TURBOCHARGER

A. GENERAL

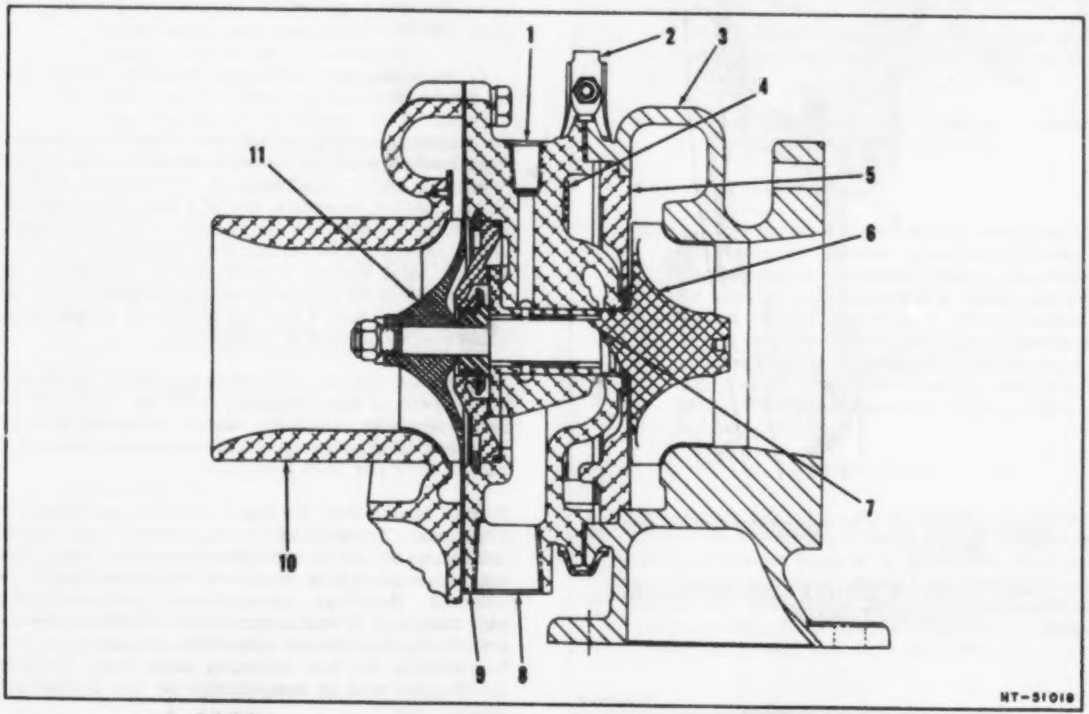
A turbocharger is used to boost the power output of an engine over that of naturally aspirated engines by increasing the supply of air to the cylinders. The "Thompson" Turbocharger is a highly efficient, yet rugged and easy to install, exhaust-driven blower. The simple, compact design of the turbocharger incorporates a single stage radial inflow turbine wheel, mounted on a common shaft with a single stage centrifugal compressor impeller. It has a one-piece bearing housing with semi-floating sleeve type bearing, a turbine housing, and a compressor housing. Both the turbine wheel and compressor impeller are individually precision balanced. Split-ring seals prevent oil leakage at the shaft ends.

B. OPERATION

During engine operation, air enters the turbocharger at center of compressor housing, Figure 2, and is discharged from compressor outlet to the intake manifold. After combustion, the exhaust gases enter the manifold and flow to turbine side of the turbocharger. The expanding gases flow rapidly through the turbine housing causing turbine wheel to spin. The turbine wheel drives the compressor impeller which is mounted on the same shaft.

The turbocharger responds to engine load demands by reacting to the flow of expanding exhaust gases and supplying a correlated volume of air to the engine cylinders. During a heavy load/lugging operation, the increased flow of exhaust gases turns the turbine wheel faster, causing the compressor impeller to turn faster to supply more air to the intake manifold. Conversely, when engine load is light and the radial flow of gases within the turbine decreases, the turbocharger compressor reduces the supply of air to the intake manifold.

The turbocharger bearing is lubricated and cooled by filtered engine oil circulating through the bearing housing under normal oil pump pressure. This oil is

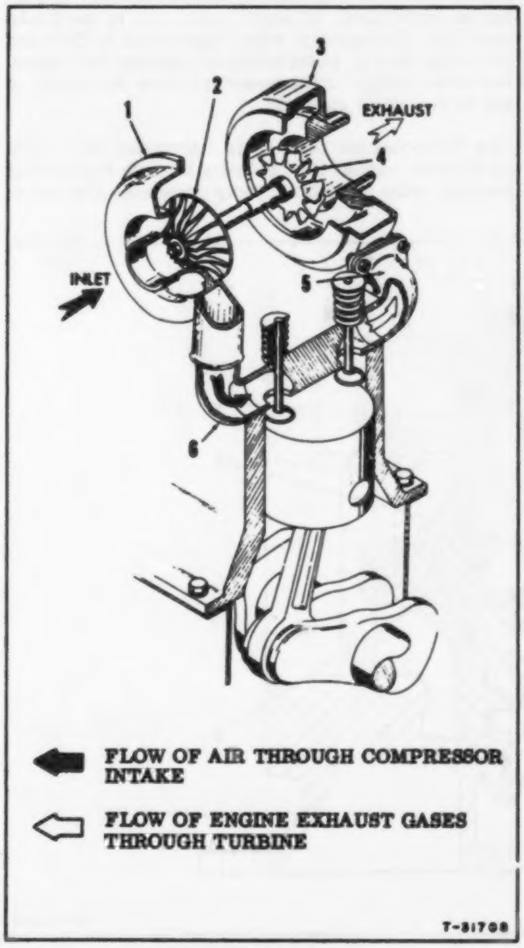


1. Oil Inlet
2. Clamp
3. Turbine Housing
4. Spring Ring
5. Turbine Shield
6. Turbine Wheel
7. Bearing
8. Oil Outlet
9. Bearing Housing
10. Compressor Housing
11. Compressor Impeller

Figure 1. Turbocharger - Sectional View

supplied to the bearing housing through an external line from the engine main oil gallery. Oil returns to the crankcase through an external line which extends from the bearing housing to the side of the cylinder block.

WARNING: Never operate the engine with air inlet piping or exhaust elbow removed from turbocharger. Clothing or foreign objects can be drawn into the compressor inlet. Discharged carbon particles and hot gases from the turbine outlet can cause personal injury.


3
2
1
EXHAUST
4
INLET
5
6
FLOW OF AIR THROUGH COMPRESSOR INTAKE
FLOW OF ENGINE EXHAUST GASES THROUGH TURBINE
T-31708

1. Compressor Housing
2. Impeller
3. Turbine Housing
4. Turbine Wheel
5. Exhaust Manifold
6. Intake Manifold

Figure 2. Turbocharger Operation Diagram

C. EFFECT OF ALTITUDE ON TURBOCHARGED ENGINES

CAUTION: To prevent damage to the engine from excessive exhaust temperatures and turbocharger overspeeding when operating at altitudes above sea level, it is necessary to consider a reduction in the maximum fuel setting of the fuel injection pump. The amount of derating is dependent upon several interrelated factors.

Altitude affects a turbocharged engine in the amount of an approximate 1% decrease in horsepower per thousand feet of altitude until an altitude is reached at which the engine must be derated and the maximum fuel setting of the fuel injection pump reduced for one of the following reasons:

1. In a continuous type operation the turbocharger must not exceed 100,000 rpm.

2. In an intermittent type operation the turbocharger must not exceed 110,000 rpm.

3. Maximum allowable exhaust temperature is 1300°F.

4. Turbocharger cavitation (surging) cannot be tolerated.

An engine operating under conditions of continuous type loading must be derated more than an engine operating under conditions of intermittent loading where loading intervals are of a time duration that does not allow stabilization of manifold temperatures and pressures, even though both may be set to deliver the same amount of horsepower. Likewise, an engine delivering near maximum horsepower must be derated more than a similar engine set to deliver a conservative amount of horsepower.

At governed speeds, exhaust temperature increases at the rate of approximately 20°F per 1000 ft altitude. However, when the engine is lugged down to 1400 to 1500 rpm the temperature may increase at a rate of 35°F per 1000 ft altitude.

Engine Model 3500 equipped with the specified 370 Thompson Turbocharger will exceed the 1300°F maximum allowable exhaust temperature before the maximum allowable speed of the turbocharger is reached. Therefore, as a practical field approach, safe control of turbocharger speed and exhaust temperature during altitude operation can be maintained by reducing the fuel injection pump flow, thereby limiting the exhaust temperature so that it does not exceed 1300°F.

NOTE: The exhaust temperature must be taken before it enters the turbocharger. The turbocharger mounting flange of the exhaust manifold is provided with 1/4" pipe plug for installing thermocouples of temperature indicators.

D. MAINTENANCE

Each time engine lubricating oil and filter elements are cleaned/replaced, or when routine service operations are performed, inspect turbocharger as follows:

1. Air Cleaner and Intake System

Restriction in the air intake system will cause malfunction of both turbocharger and engine. Back-pressure, caused by restriction, is measured as a vacuum. Back-pressure measured at the turbocharger air inlet, under engine full-speed, full-load conditions, should never exceed 30" of water.

a. Inspect gaskets, hose connections, air cleaner-to-turbocharger inlet tubing, and clamps for loose or damaged condition that permits air leaks in system.

b. Inspect for restrictions due to dented tubing or collapsed hoses.

2. Lubrication System

a. Replace engine lubricating oil and filter elements at specified intervals to assure clean supply of oil to the turbocharger.

b. Minimum oil flow to turbocharger with engine running is 10 psi with oil temperature of 180°F. Loss of engine oil pressure will quickly damage or destroy a turbocharger.

> CAUTION: If an engine has been in storage for several months without being operated, it is recommended that the oil inlet connection at the turbocharger be removed and 3 to 4 ounces of lubricant be placed in the oil inlet of the center housing. Also, fill oil inlet line with oil. Perform the above BEFORE operating engine.

c. Inspect oil inlet lines, drain lines, and fittings for leakage, clogging, and damage.

3. Exhaust System

Total restriction of the exhaust system must not exceed 1" mercury back-pressure at the turbocharger turbine housing exhaust outlet, under engine full-speed, full-load conditions. Excessive back-pressure will reduce turbine speed and subject it to excessive temperatures.

a. Inspect for exhaust leaks due to damaged gaskets, cracks in exhaust manifold, loose manifold mounting, or loose turbocharger-to-manifold mounting.

b. Observe engine exhaust. Excessive smoke may indicate a restricted air cleaner or air intake pipe, over-fueling, or faulty turbocharger operation. Check air filter service indicator and service the air filter as required.

4. Fuel Injection Pump

Under no circumstances should the factory maximum fuel delivery specification for the injection pump be exceeded in order to increase power output of the engine. Resulting turbocharger and engine damage will be costly and offset any benefit that might have been derived from increased engine power.

5. Engine Breather System

A clogged engine breather tube will cause pressure build-up in the engine. This pressure will prevent the oil from draining down the oil return line and force it out the low pressure side of the turbocharger and into the engine air intake system.

a. Check engine crankcase breather to make certain air flow is not restricted.

6. Operating Checks

a. Operate engine at approximate rated output and listen for unusual turbocharger noise. (Do not mistake whine heard during run-down for one that indicates impeller shaft bearing failure during operation.) Other unusual noises can result from improper clearance between turbine impeller and turbine housing. If such noises are heard, the turbocharger must be removed, disassembled, and inspected.

E. 2000-HOUR INSPECTION

A major inspection of the turbocharger, by an experienced turbocharger mechanic, should be made after each 2000-hour interval of operation. This inspection requires removal of the turbocharger from the engine, and removal of the compressor housing and turbine housing from the turbocharger, to check shaft radial movement and shaft end play.

TOPIC 20. SAFETY CONTROLS

A. GENERAL

The purpose of engine safety controls is to automatically stop the engine and/or audibly warn the operator to stop the engine, thereby protecting it from damage if oil pressure drops below safe operating pressure, or if coolant temperature rises above a safe, pre-set limit. Depending on owner's requirements, various combinations of safety control components are available, including an oil pressure safety switch-gauge, water temperature safety-switch gauge, magnetic switch, governor with electric shutoff, and warning horn.

The safety switch-gauges are wired to the magnetic switch that energizes or de-energizes the electric fuel shutoff solenoid in the fuel injection pump, and opens the magnetic switch circuit after shutdown to prevent battery discharge. The fuel shutoff solenoid is of the "energized to run" type.

In general, no periodic service is required other than an occasional inspection or test to make certain connections are secure and safety controls are operating properly.

B. OIL PRESSURE SWITCH-GAUGE

1. Operation

The oil pressure switch-gauge is a combination oil pressure gauge and safety switch. The visible adjustable shutdown contact and pointer on the instrument dial indicates engine oil operating pressure. The gauge is connected by tubing directly to the engine oil gallery. If oil pressure drops during operation, the pointer moves to the low pressure range of the switch-gauge and contacts the adjustment screw, stops the engine and/or activates the warning horn.

After engine has stopped for any reason, the pointer remains in contact with the adjustment screw, in which position it is impossible to start the engine. To restart engine, push reset button IN to move pointer away from contact screw. After startup, oil pressure causes the pointer to move to the operating range and the lockout arm automatically moves down to clear the pointer.

CAUTION: After resetting gauge, make sure lockout arm moves down to clear pointer.

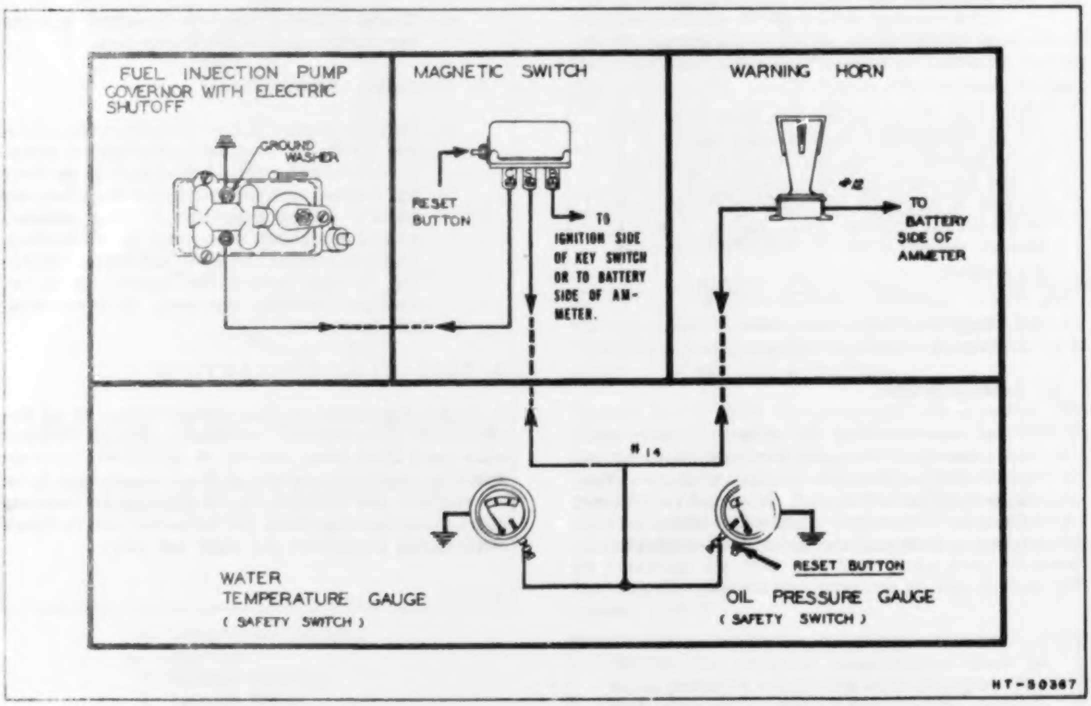
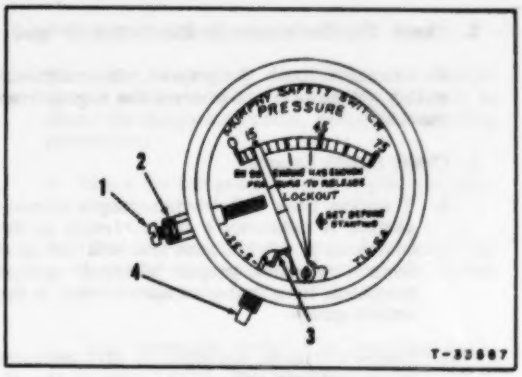

FUEL INJECTION PUMP GOVERNOR WITH ELECTRIC SHUTOFF
GROUND WASHER
MAGNETIC SWITCH
RESET BUTTON
TO IGNITION SIDE OF KEY SWITCH OR TO BATTERY SIDE OF AMMETER.
WARNING HORN
#12
TO BATTERY SIDE OF AMMETER
#14
WATER TEMPERATURE GAUGE (SAFETY SWITCH)
RESET BUTTON
OIL PRESSURE GAUGE (SAFETY SWITCH)
HT-50367

Figure 1. Low Oil Pressure - High Water Temperature - Safety Controls - Schematic Wiring Diagram



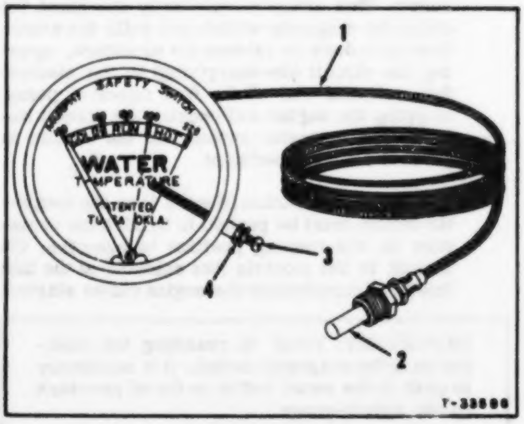
1. Contact Screw
2. Locknuts
3. Lockout
4. Reset Button

Figure 2. Oil Pressure Switch-Gauge

2. **Adjustments**

Gauge contacts are factory adjusted to shut down the engine when oil pressure falls below 10 psi. This setting can be changed to compensate for changes in operating pressures. To change settings, loosen locknuts on shutdown contact screw. With a small screwdriver, turn contact screw IN for higher pressure shutdown, or OUT for lower pressure shutdown.

CAUTION: After adjustment is made, carefully tighten locknuts to avoid cracking insulator.



1. Capillary Tube
2. Heat Bulb
3. Contact Screw
4. Locknuts

Figure 3. Water Temperature Switch-Gauge

C. WATER TEMPERATURE SWITCH-GAUGE

1. **Operation**

The water temperature switch-gauge is a combination coolant temperature gauge and safety switch. The visible adjustable shutdown contact and pointer on the instrument dial indicates temperature of engine coolant. The gauge is connected directly into the engine cooling system by a capillary tube and heat bulb. With engine running normally, gauge pointer should be in the RUN zone. If coolant temperature rises excessively, the pointer moves to the HOT zone and touches the adjustment screw contact, stopping the engine.

While pointer remains in contact with the adjusting screw, it is impossible to start the engine. It is necessary to allow coolant temperature to drop so pointer can move away from contact screw before engine will start.

2. **Adjustment**

The water temperature switch-gauge contacts have been adjusted to shut off the engine when coolant temperature reaches 205°F. This setting can be changed to compensate for altitude variations that affect the boiling point of water. To change setting, loosen locknuts on shutdown contact screw. With a small screwdriver, turn contact screw IN for lower temperature or OUT for higher temperature setting.

CAUTION: After adjustment is made, carefully tighten locknuts to avoid cracking insulator.

D. STARTING AND STOPPING PROCEDURE WITH SAFETY CONTROLS

Following is procedure for starting and stopping engines equipped with safety controls.

1. **Normal Starting**

a. Make certain load is disconnected from engine.

b. Push IN lockout reset button on oil pressure safety switch-gauge to separate pointer from contact screw.

NOTE: After engine starts, make certain pointer lockout drops back to original position.

c. Push IN reset button on magnetic switch.

d. Move throttle control to FULL LOAD position.

e. Turn key switch ON.

f. Depress starter button.

> CAUTION: The starting motor must never be used continuously for more than 30 seconds at any one time without a pause of two minutes to wait until it cools.

g. As soon as engine starts, move throttle control to FAST IDLE speed and let engine warm up.

2. Normal Stopping

a. Move throttle control knob slowly to LOW IDLE speed and disengage load from engine.

> CAUTION: Run engine for at least 5 minutes at FAST IDLE so it can cool gradually and uniformly. Then turn OFF key switch.

b. As soon as oil pressure has dropped sufficiently, the pointer of the oil pressure safety switch-gauge contacts the adjustment screw and completes the circuit to the magnetic switch coil. Simultaneously, the magnetic switch armature is released, deenergizing the governor solenoid and opening the magnetic switch circuit to prevent battery discharge.

3. Automatic Safety Engine Shutdown

a. High Coolant Temperature

If shutdown is due to high coolant temperature, pointer of water temperature safety switch-gauge remains in contact with the adjustment screw, and it is impossible to start the engine until coolant temperature is lowered sufficiently for contacts to separate.

(1) Locate source of trouble causing overheating and make necessary repairs.

(2) Fill system with coolant and start engine.

b. Low Oil Pressure

(1) If shutdown is due to low oil pressure, locate source of trouble and make necessary repairs.

(2) Make certain oil pan is filled to proper level and start engine.

E. GAUGE CIRCUIT TROUBLE SHOOTING CHECKS

If fuel and electrical systems, and the oil and coolant levels have been checked, and engine operation is still not normal, check the following:

1. Check Wiring

Make certain all connections are tight.

2. Check The Terminals On The Switch-Gauges

If terminals touch the panel, the magnetic switch will actuate and prevent the engine from running.

3. Check Switch Gauges

a. If engine runs with switch-gauges disconnected, it indicates a short circuit in the switches. If engine runs but will not shut down with switch-gauges "shorted" against the panel, it indicates an open circuit in the switch-gauge.

b. Check for gum, varnish, or dirt deposits in the damper unit on the back of the oil pressure switch-gauge.

c. Check for damage to the capillary tube or the heat bulb for coolant temperature switch-gauge.

d. Check switch-gauges for accuracy and replace if erratic performance is noted.

4. Check The Magnetic Switch

Refer to Paragraph F below.

F. MAGNETIC SWITCH

1. Purpose And Operation

A magnetic switch (circuit breaker) is wired into the circuit of the safety controls. Its purpose is to stop the engine by opening the circuit to the electric fuel solenoid coil in the fuel injection pump whenever the pointer of either the oil pressure or water temperature switch-gauge makes contact with a gauge adjustment screw. This action momentarily energizes the coil in the magnetic switch and pulls the armature latch down to release the armature, opening the circuit (de-energizing) to the electric fuel solenoid coil of the fuel injection pump, stopping the engine and opening the circuit between the magnetic switch and the battery to prevent battery discharge.

The reset push button (Figure 1) on the magnetic switch must be pushed in to latch the armature in the running position to complete the circuit to the electric fuel solenoid of the fuel injection pump before the engine can be started.

> IMPORTANT: Prior to resetting the pushbutton on the magnetic switch, it is necessary to push in the reset button on the oil pressure safety switch-gauge.

If the contacts in the oil pressure safety switch-gauge are not separated, the coil in the magnetic switch is energized and will hold down the latch which locks the armature of the magnetic switch in the running position.

2. **Magnetic Switch Service Checks**

Whenever inspecting or testing the switch-gauges and circuits, it is also necessary to check the magnetic switch, using the following procedure:

a. Check for burned out fuse. Replace as necessary.

b. Check terminals and wiring. "Shorting" the terminal S, against the panel, will unlatch the contacts and stop the engine.

c. Test magnetic switch. By pressing push-button all the way in, the ammeter should indicate discharge when in and none when released.

d. Check the S-terminal leads. If, with engine running and after normal oil pressure has separated its switch-gauge contacts, the magnetic switch will not stay latched, trouble may be isolated by removing switch-gauge leads from the S terminal, starting the engine, and touching one lead at a time to the S terminal until the faulty circuit is located.

e. Adjust switch, if necessary, as follows:

(1) Check and tighten all terminals.

(2) Check the contact latch and smooth the surface with a point file if it is rough or corroded.

(3) Make sure armature moves freely. Bend holder if necessary, to increase the spring tension.

(4) Check contacts and make certain they "make" and "break" properly with a distinct air gap when unlatched. If necessary, adjust contact arm by bending so it will "make" when contacts are latched and "break" when unlatched.

TOPIC 21. Not applicable.

TOPIC 22. POWER TAKE-OFF CLUTCH

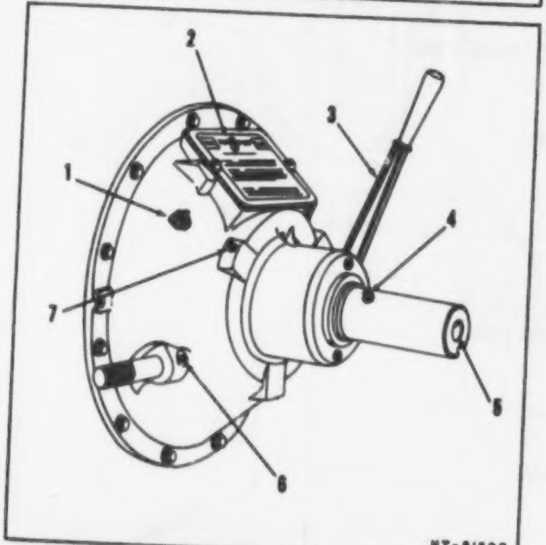
A. GENERAL

The power take-off unit contains a heavy duty, single or double plate, dry clutch, with an over center engaging action. A shifting collar and bearing mechanism, carried on the power take-off shaft, is operated by a clutch operating lever to engage or disengage the clutch. A threaded adjusting yoke provides a means of maintaining necessary adjustment to compensate for normal wear on clutch facings.

B. POWER TAKE-OFF CLUTCH SERVICE

1. Each day before operation, lubricate throw-out collar through fitting on tapered part of housing.
2. Each 100 hours of operation:
   a. Check clutch adjustment.
   b. Lubricate pilot bearing through fitting in clutch shaft.
   c. Lubricate shaft bearings through fitting on housing hub.
   d. Lubricate operating lever shaft.

CAUTION: In each case, apply a small amount of grease. DO NOT OVERGREASE.



1. Throwout Collar Lube Fitting
2. Clutch Access Cover
3. Clutch Operating Lever.
4. Pilot Bearing Lube Fitting
5. Alternate Pilot Bearing Lube Fitting Location
6. Operating Lever Shaft Lube Fitting
7. Shaft Bearing Lube Fitting.

Figure 1. Power Take-Off Clutch

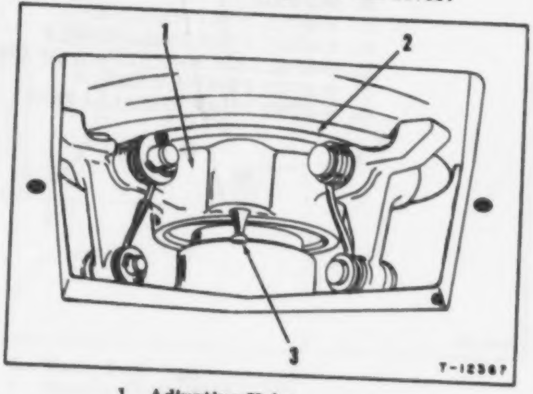
3. When the power take-off unit is used to drive a large pulley or any other device that makes the lube fitting in the side of the shaft inaccessible, remove the plug from the end of the shaft and replace it with the lube fitting. Using the plug from the end of the shaft, insert it into the side of the shaft to prevent loss of lubricant.

CAUTION: Always refer to instructions on clutch access cover.

C. POWER TAKE-OFF CLUTCH ADJUSTMENT

After each 100 hour operating interval, check clutch adjustment. Clutch should engage with a definite over-center "snap" and should require an appreciable push on the operating lever for engagement. If "snap" is not evident, or if clutch slips under load, adjust it immediately as follows:

1. Remove clutch access cover and gasket from power take-off housing.
2. Disengage clutch. Turn clutch shaft until clutch adjusting lock pin can be reached through opening in power take-off housing.
3. Pull adjusting lock pin out and turn adjusting yoke clockwise to tighten or counterclockwise to loosen. An adjustment of two or three notches is generally sufficient.
4. Lock adjusting yoke in place by inserting adjusting lock pin into nearest notch in clutch back plate.
5. When properly adjusted, clutch should engage with a definite over-center "snap".
6. Install clutch access gasket and cover.



1. Adjusting Yoke
2. Clutch Back Plate
3. Clutch Adjusting Lock Pin

Figure 2. Power Take-Off Clutch Adjustment

SECTION 2
COOLING SYSTEM

TOPIC	TITLE	
1	GENERAL	2.1
2	RADIATOR	2.2
	A. GENERAL	
	B. RADIATOR REMOVAL	
	C. RADIATOR INSPECTION AND REPAIR	
	D. RADIATOR INSTALLATION	
3	FAN, FAN BELTS, FAN SPACER, AND FAN PULLEY	2.3
	A. GENERAL	
	B. FAN BELT ADJUSTMENT	
	C. FAN BELTS, REMOVAL, INSPECTION, AND INSTALLATION	
	D. FAN, FAN SPACER AND FAN PULLEY REMOVAL, INSPECTION AND INSTALLATION	
4	ENGINE OIL COOLER	2.4
	A. GENERAL	
	B. ENGINE OIL COOLER REMOVAL AND DISASSEMBLY	
	C. ENGINE OIL COOLER CLEANING	
	D. ENGINE OIL COOLER TESTING	
	E. ENGINE OIL COOLER ASSEMBLY	
	F. ENGINE OIL COOLER INSTALLATION	
5	WATER PUMP	2.5
	A. GENERAL	
	B. SERVICE	
	C. WATER PUMP REMOVAL	
	D. WATER PUMP DISASSEMBLY	
	E. INSPECTION AND REPAIR OF WATER PUMP	
	F. WATER PUMP ASSEMBLY	
	G. WATER PUMP INSTALLATION	

TOPIC 1. GENERAL

Refer to COOLING SYSTEM Topic, in Section 1, for additional information and illustrations relative to the cooling system.

The engine cooling system includes the water pump, radiator, water inlet piping, thermostat, thermostat housing, engine oil cooler (turbocharged engine) hoses, engine coolant temperature gauge, cooling fan, coolant filter (optional equipment), and water passages in the cylinder block and cylinder head.

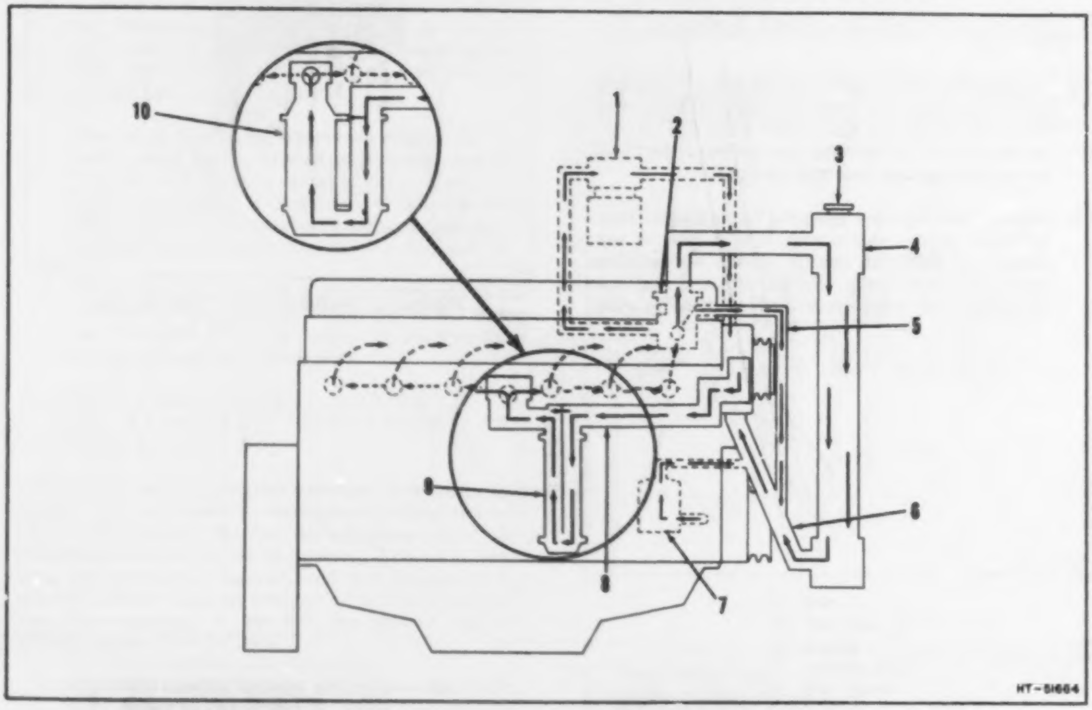
A double acting valve is provided in the radiator filler cap for relieving air pressure due to heat expansion and allowing atmospheric pressure to enter when cooling contraction occurs.

The water pump draws coolant from the bottom of the radiator and circulates it thru the water passages in the cylinder block and cylinder head. The coolant is discharged from the cylinder head thru the thermostat housing and radiator inlet hose into the upper part of the radiator. As the coolant passes from the top to the bottom of the radiator, the coolant dissipates its heat to the atmosphere by air drawn or pushed thru the radiator core by the cooling fan.

If the engine is equipped with a two-pass oil cooler, the coolant is conveyed thru a water tube from the water pump volute to the inlet of the oil cooler header which has a divider cast into it. The coolant enters one side of the header and the divider causes the coolant to be directed thru one half of the tubes in the cooling core. The bonnet at the other end of the cooler does not have a divider and the coolant is returned thru the other half of the tubes in the core (in the opposite direction) and is discharged from the outlet in the header into the cylinder block. A portion of the coolant is directed from the inlet of the header into outlet of the header thru a bypass hole.

When an air compressor is mounted on the left-front side of the engine, an inlet hose from the thermostat housing and an outlet hose to the water pump provide for the flow of coolant thru the air compressor.

When a coolant filter is mounted on the left side of the engine, an inlet hose from the cylinder block and an outlet hose to the water inlet pipe provide for the flow of coolant thru the coolant filter.



1. Air Compressor (Optional)
2. Thermostat Housing
3. Pressure Cap (7 psi)
4. Radiator
5. Bypass Hose
6. Water Inlet Pipe
7. Coolant Filter (Optional)
8. Water Tube - Pump to Oil Cooler
9. Oil Cooler
10. Torque Converter Oil Cooler (Optional)

Figure 1. Model 3500 Coolant Flow Schematic Diagram

TOPIC 2. RADIATOR

A. GENERAL

The radiator is of the fin and tube type and is properly positioned on the radiator support in relation to the cooling fan. In order for the cooling fan to provide positive full air flow through the radiator core, a shroud is provided in back of the core and surrounds the cooling fan. An overflow tube is connected to the filler neck and leads to the bottom of the radiator.

B. RADIATOR REMOVAL

1. Drain the cooling system. Refer to COOLING SYSTEM Topic, in Section 1.
2. If applicable, remove side panels, exhaust pipe, hood, fan guard, and radiator braces.
3. Loosen hose clamps attaching the radiator inlet and outlet hoses to the radiator.
4. Remove nuts, lockwashers, and washers securing the radiator to the engine base assembly and remove the radiator.

C. RADIATOR INSPECTION AND REPAIR

1. Thoroughly clean exterior of radiator removing all foreign material from between cooling cores and fins. Refer to COOLING SYSTEM Topic, in Section 1. Be careful not to bend the fins, straightening any that may be bent.
2. Inspect radiator for clogging or leakage. Test radiator under water with 4 to 5 lbs. of air pressure. Note the source of the air bubbles and solder the leaks. Be sure to wash off the acid after soldering as the acid will eat into the tubes if not washed off. The radiator should be repaired only by qualified personnel.
3. Inspect the hoses for deterioration or damage. Replace as necessary.

D. RADIATOR INSTALLATION

1. Install the radiator by a direct reversal of the removal procedure in Paragraph B.
2. Close the cooling system drain cocks. Fill system with coolant and check for leaks.

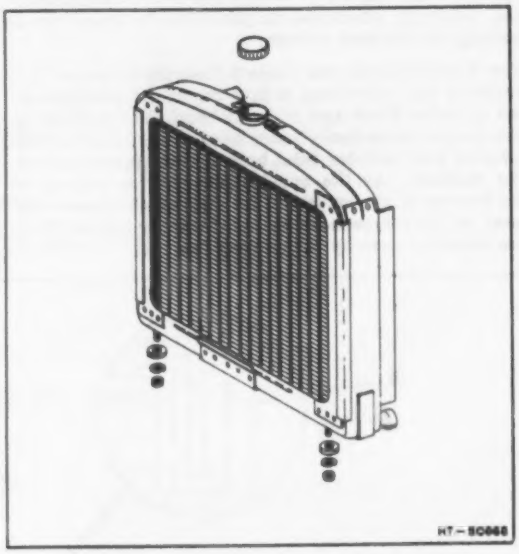


Figure 1. Radiator and Pressure Cap

TOPIC 3. FAN, FAN BELTS, FAN SPACER, AND FAN PULLEY

A. GENERAL

The engine may be equipped with either a pusher type or suction type fan depending upon the application. The fan pushes or pulls (according to the type used) air thru the radiator and the engine coolant is cooled as it circulates from the top to the bottom of the radiator core. The fan, fan spacer, and water pump fan pulley are bolted to the pulley hub which is pressed on the water pump shaft. The fan is driven from the crankshaft pulley by a pair of matched "V" type belts which also drive the battery charging alternator.

B. FAN BELT ADJUSTMENT

For fan belt adjustment procedure, refer to COOLING SYSTEM Topic, in Section 1.

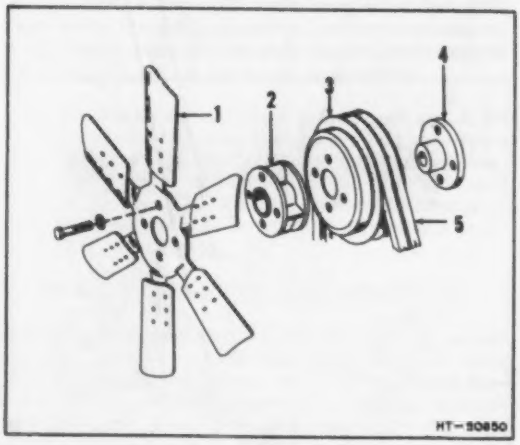
C. FAN BELTS REMOVAL, INSPECTION, AND INSTALLATION

1. If applicable remove the fan guard.
2. Loosen capscrew securing alternator to adjusting brace and push alternator in so that fan belts can be removed from alternator pulley. Slip fan belts from fan pulley and over fan blades and remove fan belts.
3. Inspect fan belts for excessive slickness, oil-soak, wear, tears, cracks, and overstretching. The fan belts are a matched pair. If only one belt replacement is required, it is imperative that both belts be replaced to assure that satisfactory belt performance will be obtained.
4. Install the fan belts by a direct reversal of the removal procedure and adjust the belts. Refer to COOLING SYSTEM Topic, in Section 1 for proper adjustment procedure.

D. FAN, FAN SPACER, AND FAN PULLEY REMOVAL, INSPECTION, AND INSTALLATION

Fan blades seldom require service. However, bent blades are conducive to inefficient cooling and will affect the balance of the fan. An unbalanced fan is detrimental to the water pump bearing. In case of damage, the fan should be removed and the blades restored to their original contour or replaced by a new fan. For removal of the fan, fan spacer, and fan pulley, proceed as follows:

1. Drain the cooling system and remove the radiator. Refer to Paragraph B, Topic 2 of this Section.
2. Remove capscrews and lockwashers securing fan and fan spacer to pulley hub; remove fan and fan spacer.
3. Loosen capscrew securing alternator to adjusting brace and push alternator in far enough so that fan belts can be removed from water pump fan pulley.
4. Slip fan belts off of fan pulley and remove water pump fan pulley from the water pump hub.
5. Inspect fan for cracks, loose rivets, or bent blades. Repair or replace if necessary.
6. Inspect fan spacer and fan pulley for wear or damage. Replace if necessary.
7. Position fan pulley on water pump hub; position fan belts in grooves of fan pulley.
8. Install fan spacer and fan securing with capscrews and lockwashers. Tighten capscrews to a torque of 43 to 48 lbs. ft. (grade 8 capscrews).
9. Adjust alternator and fan belts to proper tension.
10. Install the radiator by a direct reversal of the removal procedure. Refer to Paragraph B, Topic 2 of this section. Fill the cooling system.



1. Fan
2. Fan Spacer
3. Pulley
4. Pulley Hub
5. Fan Belts

Figure 1. Fan and Pulley Details

TOPIC 4. ENGINE OIL COOLER

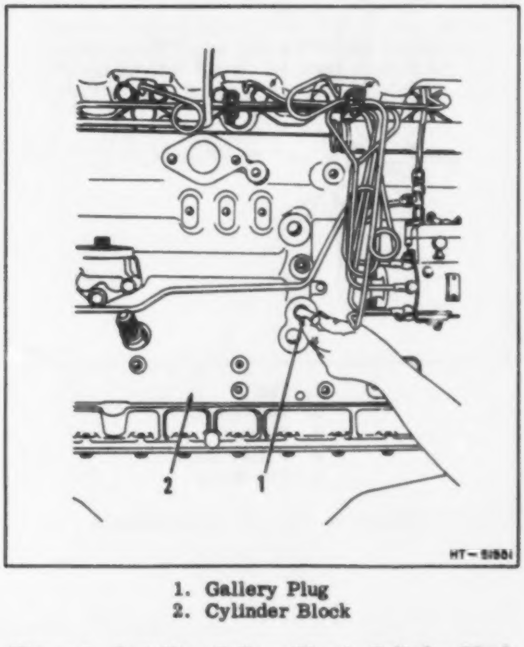
A. GENERAL

The engine oil cooler, located on the right side of the engine, consists of a corrosion resistant cooling core and tank. The water pump circulates coolant through the cooling core tubes and the engine oil pressure pump circulates oil through the tank, around the outside of the tubes of the cooling core, thereby controlling oil temperature.

The cooling core consists of small brass tubes which dissipate heat from the oil to the engine coolant. If the proper lubricating oil maintenance procedure is followed, the oil cooler will function efficiently. However, if the oil in the engine is not changed at the recommended intervals, impurities will be deposited in the cooler and will restrict the flow of oil around the tubes of the cooling core. Restriction of the flow of oil through the oil cooler is usually indicated by a drop in oil pressure, due to the oil overheating. If this occurs, the oil cooler must be cleaned or replaced with a new one.

> IMPORTANT: It is absolutely necessary that the oil cooler be kept clean for proper oil cooling.

The Model 3500 engine is equipped with a two-pass oil cooler. The term "two-pass" refers to coolant flow, not to engine oil flow. The coolant inlet and outlet are located in the same end bonnet which has a divider cast into it. The coolant enters one side of the bonnet and the divider causes the coolant to be directed through one-half of the tubes in the cooling core. The bonnet at the other end of the cooler does not have a divider and the coolant is returned through the other half of the tubes in the core (in the opposite direction) and is discharged from the outlet. Thus, the coolant makes two passes through the cooler.



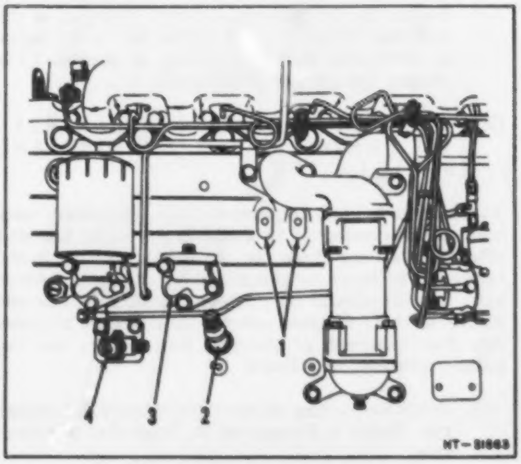
1. Gallery Plug
2. Cylinder Block

Figure 1. Installing Gallery Plug in Cylinder Block

Whenever an engine is equipped with an oil cooler, the cylinder block is equipped with a gallery plug which is required when an oil cooler is used. However, if for some reason that an engine, previously equipped with an oil cooler, is to be run with the oil cooler removed from the engine, the gallery plug also must be removed from the cylinder block to maintain proper oil pressure and lubrication.

B. ENGINE OIL COOLER REMOVAL AND DISASSEMBLY

1. Drain the cooling system; also remove drain plug from bottom of oil cooler and drain coolant from oil cooler.
2. Remove fuel filter to fuel pump supply line. Remove fuel line between hand primer pump and fuel filter. Remove fuel filter head with filter element intact. Refer to Figure 2.
3. Remove turbocharger drain tube assembly between turbocharger and cylinder block.
4. Remove front lube oil filter element only to facilitate removal of engine oil cooler.



1. Fuel Filter Mounting Pads
2. Turbocharger Oil Drain Fitting
3. Lube Filter Base
4. Hand Primer Pump

Figure 2. Preparing for Removal of Oil Cooler

5. Remove capscrews and lockwashers securing oil cooler assembly to cylinder block and remove oil cooler assembly by pulling towards the rear of engine.

6. Remove water tube with O-rings from the volute.

7. Place oil cooler assembly on a bench and remove the capscrews and lockwashers attaching the header and bonnet to the oil cooler (core).

8. Separate the pieces by removing header, bonnet, and gaskets from oil cooler. Remove and discard the O-rings. Remove and discard the O-rings from the water tube.

9. Clean and inspect oil cooler and components.

C. ENGINE OIL COOLER CLEANING

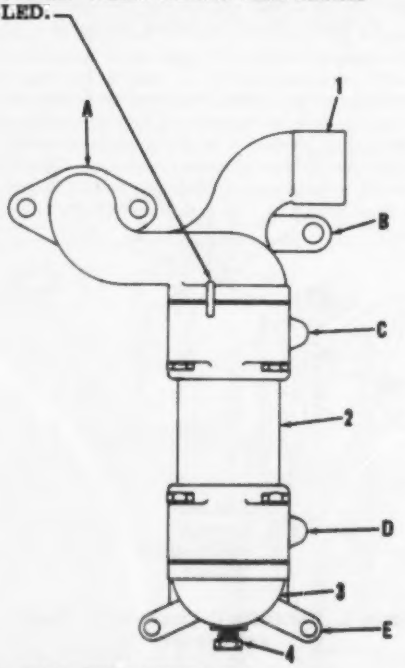
Thorough cleaning of the oil cooler may require use of special solvents. Several solvents for this purpose are available and must be used according to manufacturer's directions. Some of the solvents are:

Excello Floor Cleaning Compound
Turco Cleaning Compound
No. 70 Stripper
Mixture of 3 parts Oakite No. 7 and 5 parts fuel oil
Bendix Cleaning Compound

To use the last-named solvent, merely submerge oil cooler into the solution for a sufficient length of time to allow chemical action of the solvent to dissolve or loosen sludge or other foreign matter. Flush oil cooler thoroughly with live steam or spirits after cleaning, regardless of type of cleaner used.

NOTE: If oil cooler core is badly clogged, a new oil cooler core must be installed.

NOTE: CAST NOTCH IN HEADER MUST LINE UP WITH CAST NOTCH IN OIL COOLER WHEN PARTS ARE ASSEMBLED.



NOTE: MACHINED SURFACES A, B, C, D, AND E MUST BE IN THE SAME PLANE AND WITHIN 0.005".

1. Header
2. Oil Cooler
3. Return Bonnet
4. Drain Plug

Figure 3. Lube Oil Cooler Assembly

D. ENGINE OIL COOLER TESTING

Before testing the oil cooler, it must be cleaned thoroughly and inspected. To test the oil cooler, proceed as follows:

1. Make up two suitable improvised plates, one with a drilled and tapped hole to accept an air hose fitting, and secure them with C clamps to cover the oil inlet and outlet openings in the side of the oil cooler. Use the O-rings to seal the plates.

2. Attach an air hose to the drilled and tapped plate; submerge the oil cooler in hot water for a sufficient length of time until the oil cooler is up to approximately 150°F. temperature. Test for leaks with air pressure of 200 psi or as near to that pressure as possible.

3. Air bubbles observed at either open end of the oil cooler indicates that the cooling core has a puncture or may be defective in another way. If the cooling core is faulty, the oil cooler must be replaced. If repair of the shell is necessary, the repair should be made by a reputable radiator repair shop.

E. ENGINE OIL COOLER ASSEMBLY

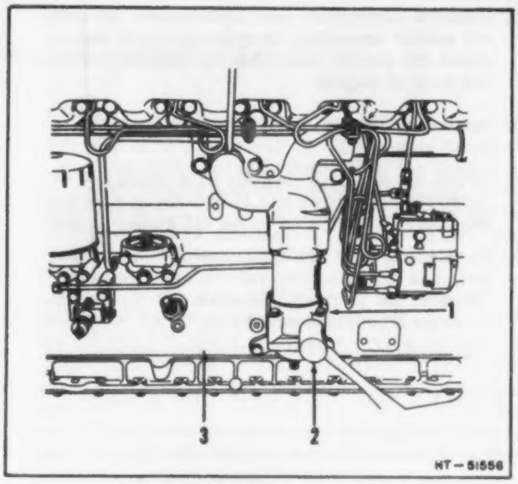
It is strongly recommended that all of the oil cooler components must lay flat on a surface plate when they are assembled, so that all of the machined surfaces A, B, C, D, and E in Figure 3 contact the surface plate and are within .005" maximum allowable clearance. However, if a surface plate is not available use the following procedure:

1. Use a new gasket and assemble oil cooler to the header so that the word TOP is up on the early models or so that the cast notch on the oil cooler is lined up with the notch on the header on the current models. Use a new gasket and assemble the other end of the oil cooler to the return bonnet. Tighten capscrews with lockwashers snug or only tight enough so cooler can shift when tapped with a soft headed hammer.

2. Clean all mounting surfaces thoroughly on the cylinder block.
3. Position oil cooler assembly only on cylinder block and install five capscrews with lockwashers and tighten securely.
4. Tap oil cooler (top and bottom) with a soft headed hammer (Figure 4) until the inlet and outlet surfaces of the oil cooler are within .005" of the mounting surfaces of the cylinder block. Insert a feeler gauge to check the clearance.
5. After the oil cooler has been aligned properly loosen the two bottom capscrews securing the oil cooler bonnet flange to the cylinder block. Then tighten the capscrews securing the header and bonnet to the oil cooler.
6. Remove the capscrews and lockwashers and once again remove the oil cooler assembly from the engine.
7. Retighten the capscrews and carefully place the oil cooler on a surface plate preferably or sheet of glass. Using a feeler gauge, check to see if all machined surfaces contact the plate within the .005" maximum allowable clearance.

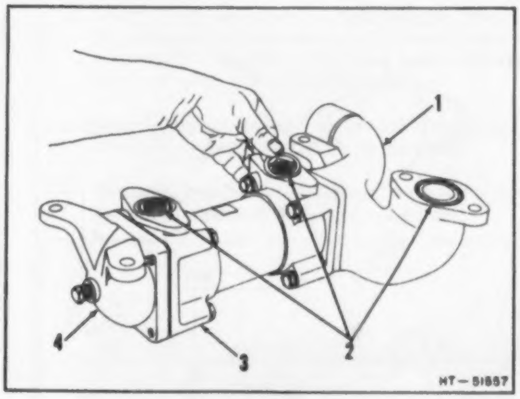
ENGINE OIL COOLER INSTALLATION

1. Assemble new O-rings on water tube and install one end of the water tube into the volute.
2. After oil cooler is assembled to the specified tolerance, install new O-rings in the back of the oil cooler assembly (Figure 5). Hold in place with a light coating of lubriplate.
3. Install oil cooler assembly by positioning header over the rear end of the water tube and pushing forward.
4. Install capscrews and lockwashers securing cooler assembly to cylinder block and tighten capscrews securely.
5. Install oil cooler drain plug and complete the installation by reversing the removal procedure.
6. Fill cooling system.
7. Operate engine and check for oil and water leaks at oil cooler connections. Correct any leaks found. Stop engine and check crankcase oil level in oil pan; add oil as necessary to raise oil level to the full mark on the dipstick. Check coolant level in the radiator and add coolant if necessary.



1. Oil Cooler
2. Soft Headed Hammer
3. Cylinder Block

Figure 4. Aligning Oil Cooler Surfaces With Cylinder Block Mounting Surfaces



1. Header
2. O-rings
3. Oil Cooler
4. Bonnet

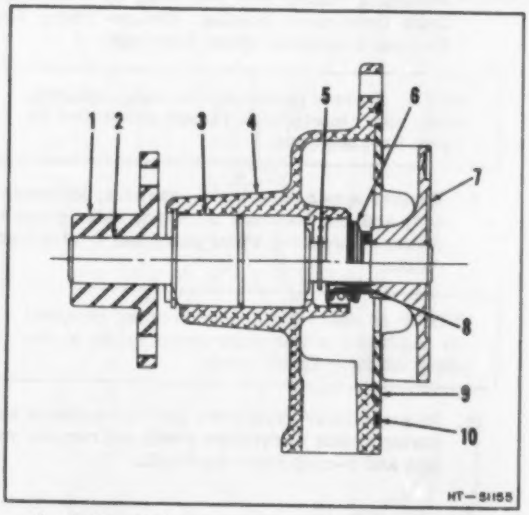
Figure 5. Installing O-rings on Oil Cooler and Header

TOPIC 5. WATER PUMP

A. GENERAL

A centrifugal type water pump is provided for circulating coolant through the engine and radiator. The water pump is mounted on the front of the cylinder block and is belt driven from the crankshaft pulley. Coolant is drawn through the inlet opening by the pump impeller and forced through the outlet opening located in the back side of the volute and into the cylinder block. If the engine is equipped with an oil cooler, the coolant is forced through the outlet of the volute into and through the oil cooler and then into the cylinder block. Also, a portion of the coolant is forced through the volute into the cylinder block. O-ring gaskets are used to assure leak proof connections.

The water pump shaft and bearing assembly does not require lubrication because the bearing is of the sealed-for-life type. A water slinger on the pulley end of the shaft slings any coolant which might seep past the seal assembly out the cored opening in the pump body, thus preventing coolant from coming in contact with the shaft bearing. The shaft and bearing assembly is secured in the pump body by a press fit and a retaining snap ring. The seal between the impeller and pump body is of the packless type. The seal assembly is spring loaded and is pressed into the pump body forming a leakproof seal at this point. The carbon sealing surface is bonded to the seal assembly and contacts a ceramic seal insert bonded to the pump impeller. Proper positioning of the impeller on the shaft creates a 9 - 13 pound load on the seal assembly forming a tight seal. The ceramic seal insert bonded to the impeller cannot be serviced separately. If it is damaged, a new impeller must be installed in the pump. A pulley hub, pressed on the front end of the water pump shaft and bearing assembly, is the mounting member for the pulley and fan.



1. Pulley Hub
2. Shaft
3. Bearing
4. Water Pump Body
5. Slinger
6. Seal Assembly
7. Impeller
8. Ceramic Seal
9. Body Plate
10. O-ring

Figure 1. Water Pump Assembly

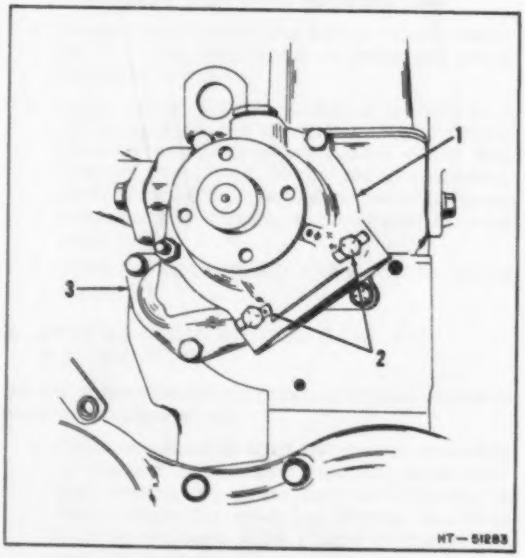
B. SERVICE

The construction of the water pump is conducive to long life with minimum attention, providing that only clean coolant is poured into the cooling system and care is taken to keep grit and abrasive material from being circulated through the system. Water containing scale-forming elements is especially harmful to pump parts.

> CAUTION: Do not use anti-freeze solutions that are harmful to aluminum.

C. WATER PUMP REMOVAL

1. Drain cooling system. Refer to COOLING SYSTEM Topic, in Section 1.
2. Remove clamps and remove inlet and outlet radiator hoses.
3. Remove radiator.
4. Loosen capscrews securing fan and pulley to water pump hub.



1. Water Pump
2. Tab Washers
3. Volute

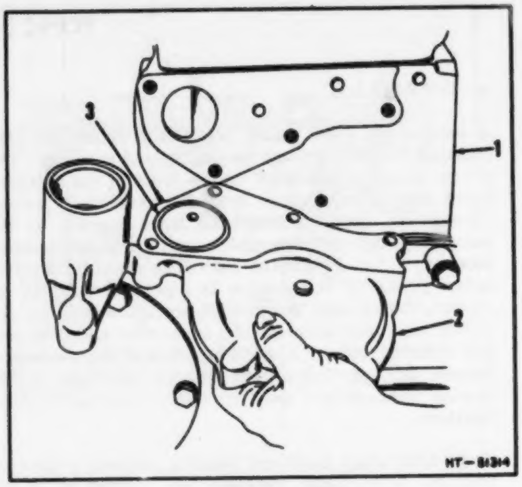
Figure 2. Water Pump and Capscrew Location

Figure 3. Not applicable.

5. Loosen capscrew securing alternator at slotted end of brace. Push alternator forward to relieve tension on belts and remove drive belts.

6. Remove the loosened capscrews, fan, fan spacer, and pulley from water pump hub.

Figure 4. Not applicable.



1. Cylinder Block
2. Volute
3. O-ring

Figure 5. Back Side of Model 3500 Volute

7. Remove nut, lockwasher and capscrew, washer, and lockwasher securing alternator brace; remove alternator brace.

8. Remove capscrews, washers, and lockwashers securing water inlet pipe to water pump. Remove water inlet pipe with by-pass hose by loosening clamp and removing by-pass hose from thermostat housing. Remove clamp and by-pass hose from water inlet pipe.

NOTE: If water pump only is being replaced, allow water inlet pipe to remain suspended by water by-pass hose.

9. Remove upper capscrews, washers, lockwashers, and tab washers securing water pump to volute and remove water pump and O-ring from volute.

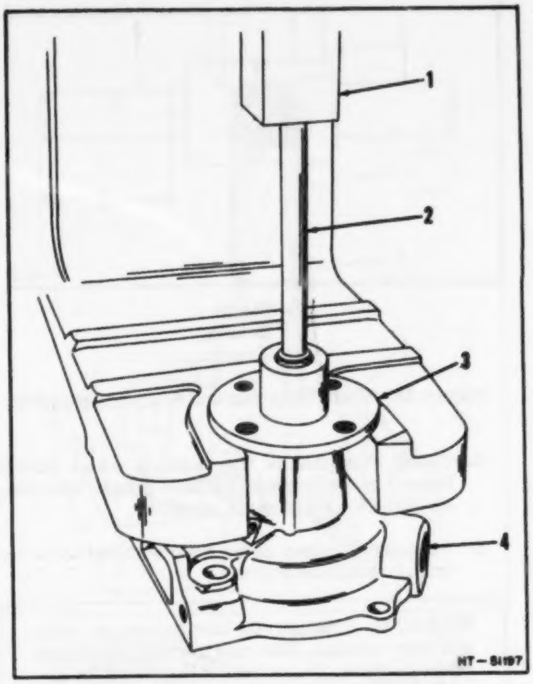
NOTE: If water pump only is being repaired or replaced, allow water pump volute to remain on the cylinder block.

10. Remove lower capscrews and lockwashers securing volute to cylinder block and remove volute and O-ring from the block.

D. WATER PUMP DISASSEMBLY

With the water pump removed from the engine, disassemble it in the following manner:

1. Place water pump assembly in position on a press and remove the pulley hub.



1. Press Ram
2. Rod
3. Pulley Hub
4. Water Pump

Figure 6. Removing Water Pump Pulley Hub

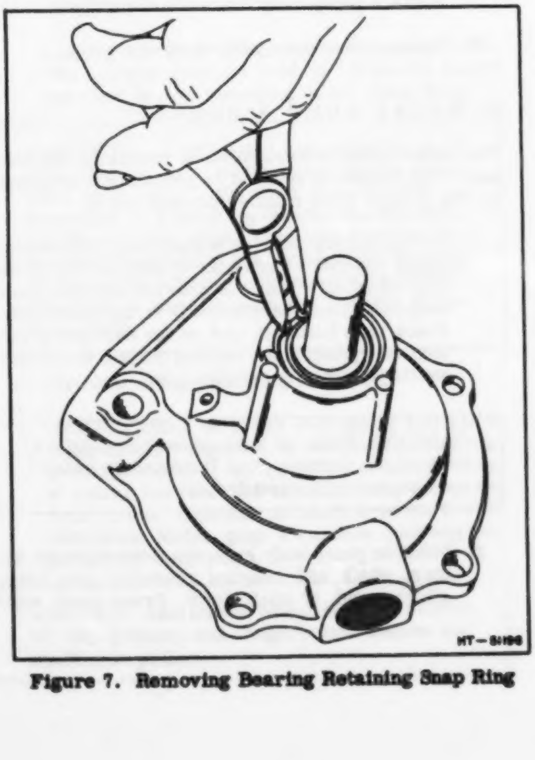
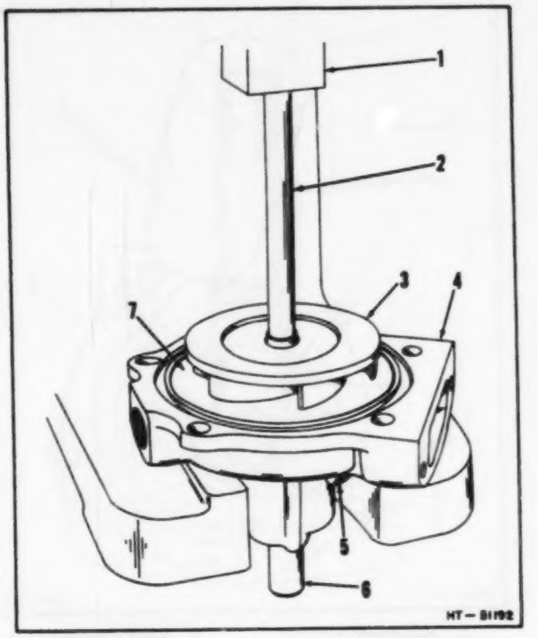


Figure 7. Removing Bearing Retaining Snap Ring



1. Press Ram
2. Rod
3. Impeller
4. Water Pump Body
5. Drain Hole
6. Shaft
7. Body Plate

Figure 8. Removing Impeller, Shaft, and Bearing Assembly

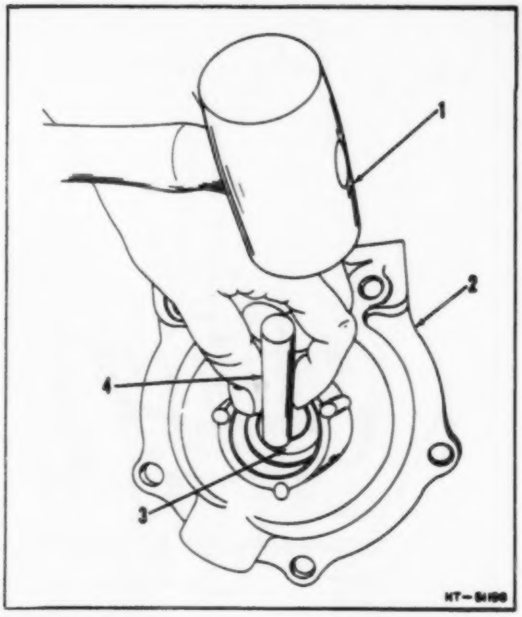
2. Using a pair of snap ring pliers, remove bearing retaining snap ring from pulley hub end of the pump body.
3. Place water pump assembly in position on a press, impeller end up. Make certain the pump rests on back of pump body and not on the water inlet or drain hole. Press end of shaft until shaft and bearing assembly is out of the pump body. Remove impeller and body plate from the pump body.
4. Drive out seal assembly with a drift or rod and a hammer.

E. INSPECTION AND REPAIR OF WATER PUMP

Repair to the water pump consists of replacement of worn or damaged parts.

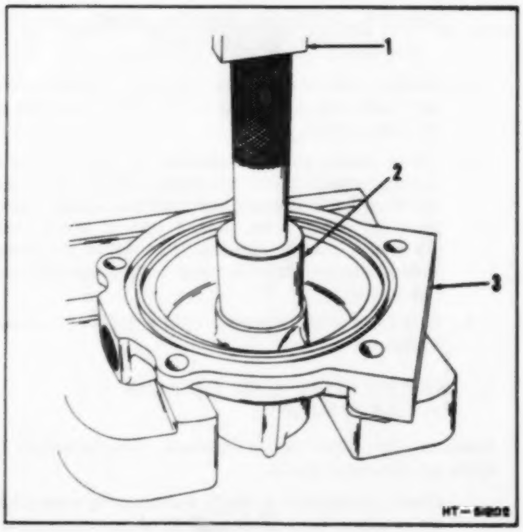
1. Check condition of shaft and bearing assembly by rotating the bearing. If the bearing is binding, running dry from lack of lubricant, or feels rough, the shaft and bearing assembly must be replaced. If the slinger is damaged, it must be replaced.

CAUTION: Do not clean shaft and bearing assembly in cleaning solvent because the lubricant will be washed from the bearing.



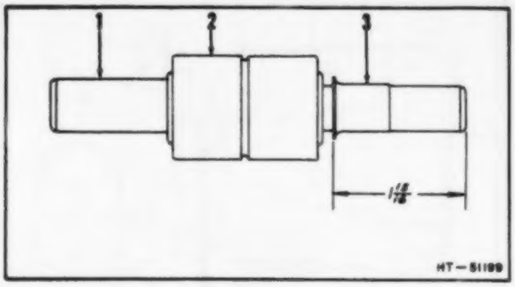
1. Hammer
2. Water Pump Body
3. Seal Assembly
4. Drift

Figure 9. Removing Seal Assembly



1. Press Ram
2. Seal Installer Tool
3. Water Pump Body

Figure 10. Installing Seal Assembly



1. Shaft
2. Bearing
3. Slinger

Figure 11. Shaft, Bearing and Slinger Assembly

2. Check condition of the ceramic seal insert bonded to the impeller. If it is rough, cracked, or chipped, replace the impeller.

3. Thoroughly clean pump body with kerosene or trichlorethylene solvent.

WARNING: Trichlorethylene solvent is toxic and very volatile. Use only in a well ventilated room or area. Do not inhale fumes for an extended length of time. Do not use cleaning solutions that are harmful to aluminum.

4. Check condition of bearing bore in the body. Replace pump body if cracks are evident.

5. Replace the water pump seal assembly.

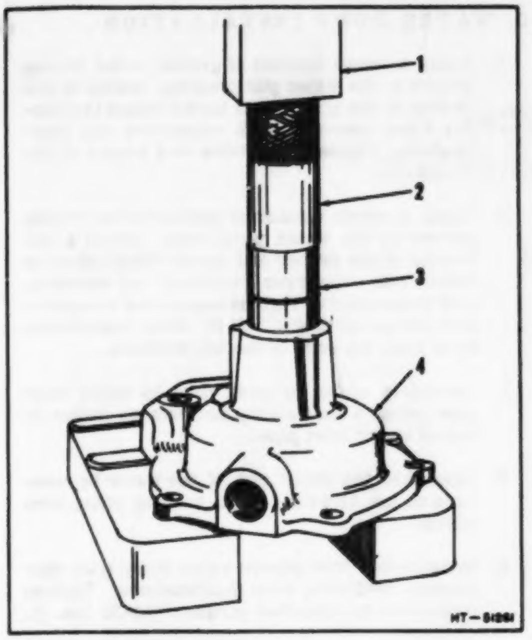
F. WATER PUMP ASSEMBLY

The water pump is assembled by reversing the disassembly sequence detailed in preceding Paragraph D. See Figure 1 for relative parts location.

1. Position pump body on press, impeller end up. Apply Number 3 Permatex to that portion of the seal assembly which is pressed into the pump body. Position seal assembly in the pump body. Place seal installer tool on the seal and press seal into pump body, making certain the carbon sealing surface is not damaged.

CAUTION: Face of seal assembly must be free of oil, grease, and fingerprints before seal assembly is installed.

2. Position pump body on press, bearing bore up. Start shaft and bearing assembly into bore, slinger end of shaft down. Press shaft until



1. **Press Ram**
2. **Installer Tool**
3. **Shaft, Bearing and Slinger Assembly**
4. **Water Pump Body**

Figure 12. Installing Shaft, Bearing and Slinger Assembly

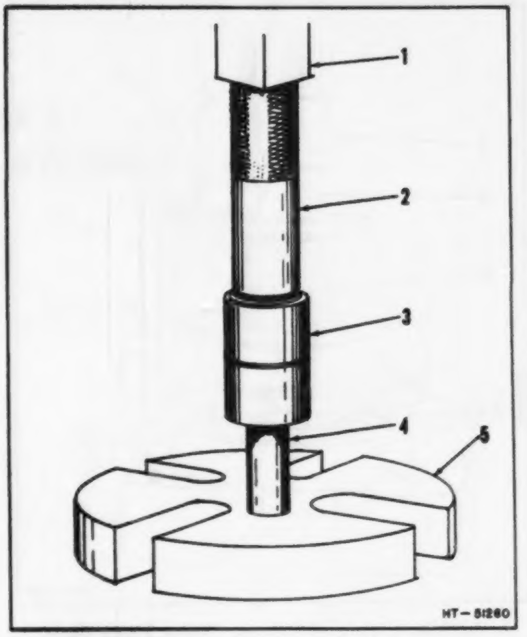
bearing seats on shoulder in the pump body. The slinger must be 1-15/16" from the end of the shaft before installing in the pump body.

> **CAUTION: [illegible] not force the bearing shaft assembly into the pump body by putting pressure on the end of the shaft. Use the tool illustrated [illegible] Figure 12, which puts the force on the outside race. This will prevent the possibility of pitting the races of the bearing by the balls within it when more force than required is used to seat the bearing in the pump body.**

3. **Install bearing retaining snap ring.**

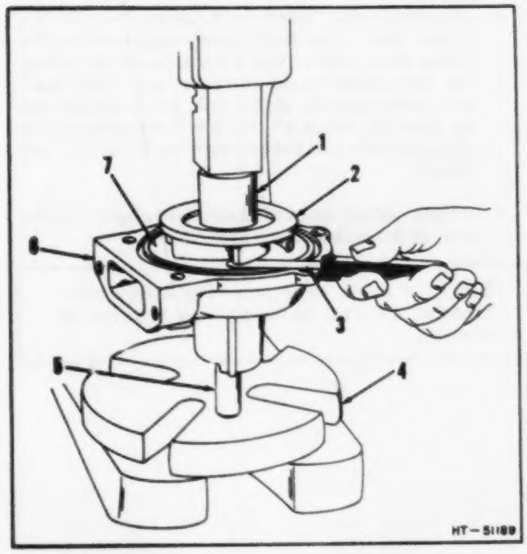
4. **Position pump on press with pulley hub end of shaft firmly supported on the press base plate. Position impeller on upper end of shaft. Using a collar between the impeller and the press ram, press impeller on shaft to attain 0.015" maximum feeler gage clearance between impeller and body plate.**

> **CAUTION: Seal face of impeller must be free of oil, grease, and fingerprints before installing impeller.**



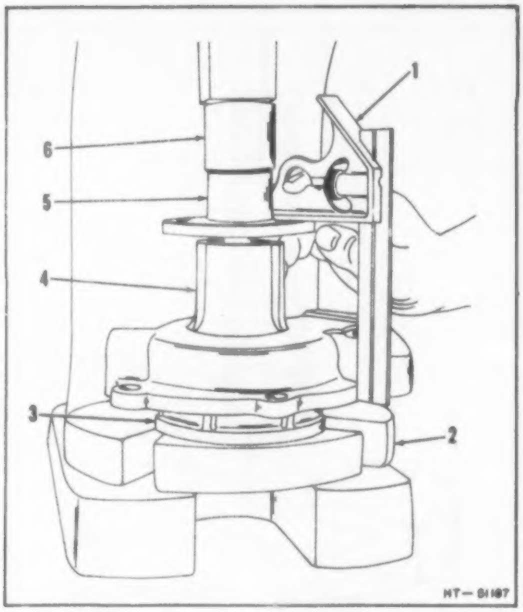
1. **Press Ram**
2. **Slinger Installer Tool**
3. **Bearing**
4. **Shaft**
5. **Press Base Plate**

Figure 13. Positioning Slinger on Water Pump Shaft



1. **Collar**
2. **Impeller**
3. **Feeler Gauge**
4. **Press Base Plate**
5. **Shaft**
6. **Water Pump Body**
7. **Body Plate**

Figure 14. Installing Impeller and Checking Clearance



1. Square
2. Press Base Plate
3. Impeller
4. Water Pump Body
5. Pulley Hub
6. Collar

Figure 15. Installing Water Pump Pulley Hub

5. Position water pump on a press with the impeller end of the shaft firmly supported on the press base plate. Use a collar between pulley hub and press ram because the end of the shaft protrudes beyond pulley hub; press pulley hub on shaft to within 4" (±0.010") between bottom of pump body and the fan side on the pulley hub flange.

6. Rotate pulley hub and check for proper operation of the water pump assembly.

NOTE: A slight drag caused by mating surfaces of the seal assembly and impeller is normal.

G. WATER PUMP INSTALLATION

1. **Apply a small amount of grease to the O-ring groove in the water pump volute. Install a new O-ring in the groove and install volute to cylinder block securely with capscrews and lockwashers. Tighten capscrews to a torque of 28-33 lbs. ft.**

2. **Apply a small amount of grease to the O-ring groove in the water pump body. Install a new O-ring in the groove and install water pump to volute with capscrews, washers, tab washers, and lockwashers. Tighten capscrews to a specified torque of 28-33 lbs. ft. After installation bend over the ends of the tab washers.**

3. **Assemble water by-pass hose to water inlet pipe using a hose clamp and cement gasket on end of water inlet pipe.**

4. **Assemble the other end of the water by-pass hose to the thermostat housing using hose clamp.**

5. **Install water inlet pipe to water pump with capscrews, washers, and lockwashers. Tighten capscrews to specified torque of 28-33 lbs. ft.**

6. **Install alternator brace using capscrew, washer, and lockwasher on slotted end. Install nut and lockwasher on other end to special water pump capscrew.**

7. **Install pulley, fan spacer, and fan to water pump pulley hub with capscrews and lockwashers. Tighten capscrews to specified torque of 30-35 lbs. ft.**

8. **Install drive belts.**

9. **Adjust to proper fan belt tension and tighten capscrew and nut on alternator brace securely. Refer to COOLING SYSTEM Topic, in Section 1 for belt adjustment.**

10. **Install radiator and supports. Install radiator inlet and outlet hoses using hose clamps.**

11. **Fill cooling system. Refer to COOLING SYSTEM Topic, in Section 1.**

SECTION 3
ELECTRICAL SYSTEM

TOPIC	TITLE	
1	GENERAL	3.1

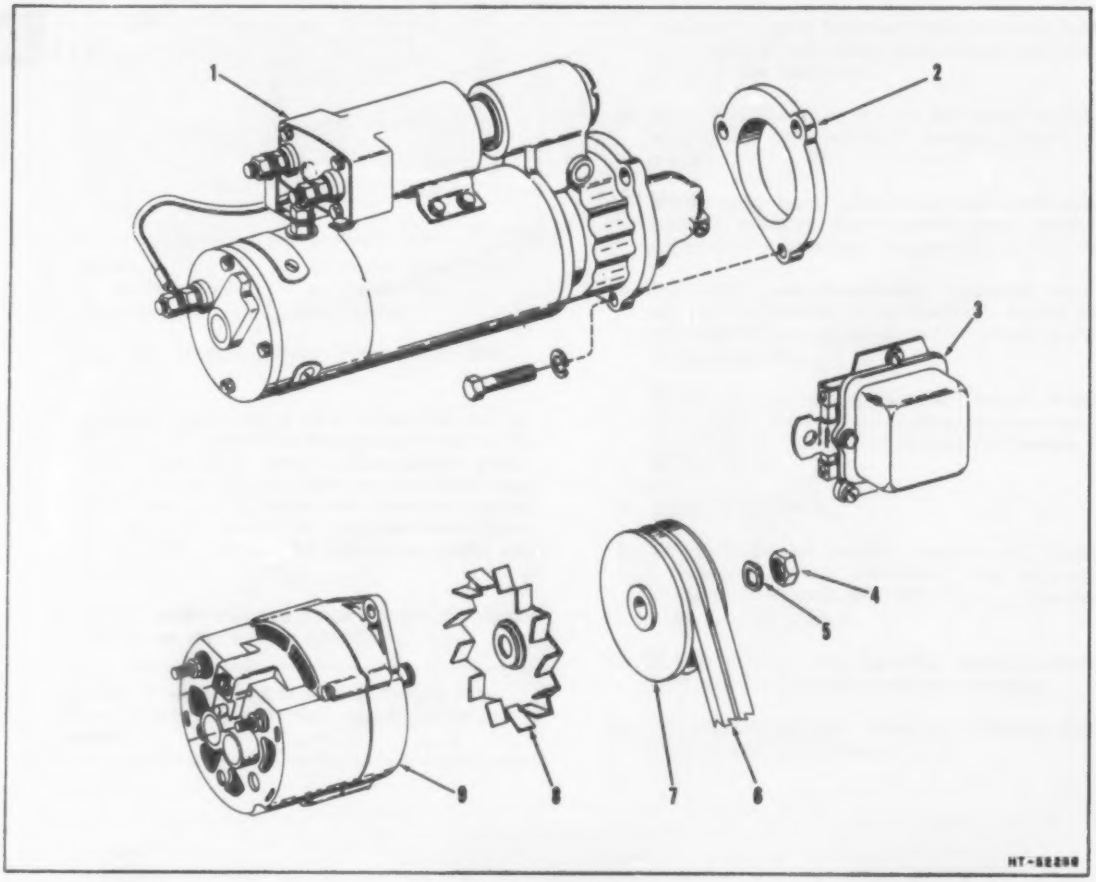
3

TOPIC 1. GENERAL

Major electrical components (Figure 1) are warranted by their manufacturer. Due to the warranty, overhaul procedures are not recommended. Any claim for replacement or repair of any of these units must be presented to the manufacturer, not to the Allis-Chalmers Manufacturing Company. For maintenance, wiring diagrams, cautions, service procedures, and warranty, refer to ELECTRICAL SYSTEM Topic in Section 1.

The electrical system consists of battery, alternator, voltage regulator, air heater, air heater solenoid, ammeter, cable and wiring system, and starter.

The basic units of the charging circuit are the batteries, alternator, and regulator. The batteries are the storage plant for electrical energy and must be kept fully charged while using a minimum amount of water. Electrical energy, drained from the batteries, is replaced by the alternator. Too much power output will usually burn out the alternator or damage the batteries. To prevent this, a voltage regulator is connected into the circuit.



1. Starter
2. Starter Adaptor
3. Voltage Regulator
4. Alternator Shaft Nut
5. Shaft Nut Washer
6. Alternator Drive Belts
7. Alternator Pulley
8. Alternator Fan
9. Alternator

Figure 1. Electrical System Components

SECTION 4.
FUEL SYSTEM

The overhaul information contained within this Section is supplemental to that service information given in Section 1. For the fuel system description, service, and adjustments, refer to FUEL SYSTEM Topic, Section 1.

TOPIC **TITLE**

1 FUEL INJECTION NOZZLE HOLDER ASSEMBLIES 4.1
  A. FUEL INJECTION NOZZLE HOLDER OPERATION
  B. FUEL INJECTION NOZZLE HOLDER CLEANING AND INSPECTION

2 FUEL INJECTION PUMP AND GOVERNOR 4.2
  A. GENERAL

3 FUEL INJECTION PUMP DRIVE GEAR, DRIVE SHAFT, AND MOUNTING ADAPTOR 4.3
  A. GENERAL
  B. FUEL PUMP DRIVE GEAR REMOVAL AND INSTALLATION
  C. FUEL PUMP DRIVE SHAFT REMOVAL AND INSTALLATION
  D. FUEL PUMP MOUNTING ADAPTOR REMOVAL AND INSTALLATION

4 HAND PRIMER PUMP 4.4
  A. GENERAL
  B. REMOVAL AND DISASSEMBLY
  C. PRIMER PUMP INSPECTION
  D. PRIMER PUMP ASSEMBLY AND INSTALLATION

TOPIC 1. FUEL INJECTION NOZZLE HOLDER ASSEMBLIES

A. FUEL INJECTION NOZZLE HOLDER OPERATION

The metered quantity of fuel under pressure, delivered by the fuel injection pump, enters the fuel inlet passage of the nozzle holder, passes through the holder fuel duct into the nozzle fuel duct via the annular groove in the nozzle body, and then into the pressure chamber above the nozzle valve seat. At the instant the pressure of the fuel in the pressure chamber exceeds the pressure exerted on the spindle and the nozzle valve by the spindle spring, the nozzle valve is lifted off its seat and the fuel is forced through the orifices in the end of the valve body and into the corresponding combustion chamber of the engine. The nozzle valve is returned to its seat by the pressure exerted by the spindle spring as soon as the fuel injection pump has ceased to deliver fuel to the nozzle holder.

There is a certain amount of fuel seepage between the lapped surfaces of each nozzle valve and valve body which is necessary for lubrication. This leakage of fuel accumulates around the spindle and in the spring compartment of the fuel nozzle, and is returned through the fuel drip manifold and fuel return lines to the fuel tank.

B. FUEL INJECTION NOZZLE HOLDER CLEANING AND INSPECTION

Before starting the disassembly of a fuel injection nozzle holder, it is of the utmost importance to have a clean work bench, clean washing fluid containers, clean tools, and clean hands. Cleanliness is emphasized because injection nozzle service troubles are, in most instances, due to dirt entering the nozzles. Use clean paper on the work bench and as the nozzle holder is disassembled, place the components in a container of clean diesel fuel as a protection against dirt and corrosion.

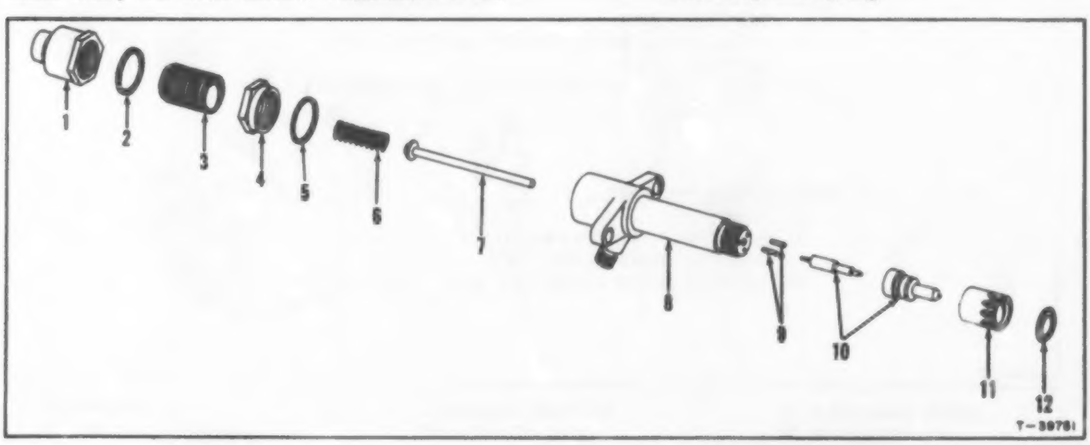
When more than one fuel injection nozzle holder is disassembled, keep parts of each separate. Complete disassembly of the fuel injection nozzle holder is seldom necessary. In most cases only disassembly and cleaning of the nozzle valve body and valve is required to place the nozzle holder in good operational condition. The nozzle valve and nozzle valve body are mated parts, and must be kept together; if replacement of either part is necessary, both parts must be replaced as matched sets. Remove, clean, and inspect the nozzle valve body and valve as follows:

1. Nozzle Valve Body and Valve Disassembly, Cleaning, and Assembly.

   a. Remove the fuel injection nozzle holder following the instructions in FUEL SYSTEM Topic, Section 1.

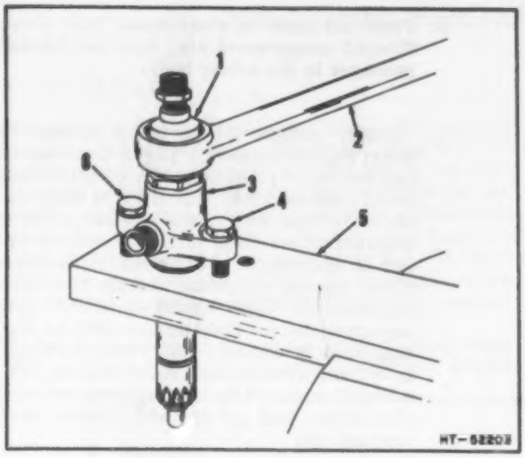
   b. Clamp nozzle holder body in a holding fixture similar to the one illustrated in Figure 2

   c. Remove cap nut and gasket from upper end of nozzle holder. Loosen pressure adjusting screw locknut and turn pressure adjusting screw out sufficiently to release spring tension on spindle spring.



1. Cap Nut
2. Gasket
3. Adjusting Screw
4. Locking Nut
5. Gasket
6. Spindle Spring
7. Spindle
8. Holder Body
9. Dowel Pins
10. Nozzle Assembly
11. Retaining Nut
12. Gasket

Figure 1. Fuel Injection Nozzle Holder Details



1. Cap Nut
2. Wrench
3. Nozzle Holder Assembly
4. Capscrew
5. Injection Nozzle Holding Fixture
6. Capscrew

Figure 2. Removing Nozzle Cap Nut

d. Using a suitable socket or box wrench, loosen and remove the nozzle retaining nut. Remove the nozzle valve body and nozzle valve from the retaining nut. Start the nut back onto the holder body to protect the lapped end of the holder body.

e. Withdraw the valve from the valve body and place them in Allis-Chalmers carbon and rust remover solution for cleaning. Normally, the valve can easily be withdrawn from the valve body, however, in some cases it may be necessary to soak the valve body and valve in the carbon and rust remover solution before the valve can be withdrawn.

> CAUTION: Do not allow the solution to get on the hands or body; use tweezers or the basket method to handle the parts. For faster and better cleaning results, the carbon and rust remover solution should be heated to approximately 200°F. The parts generally can be separated in two or three minutes; however, for stubborn cases they can be left in the solution longer.

After removing the parts from the solution, immediately place them in clean diesel fuel for neutralizing. Always handle the parts carefully to protect the lapped surfaces.

f. The valve seat and the seat in the valve body are originally ground to slightly different angles to provide a line contact seat between the two parts. Practically all the wear occurs in the seat in the valve body. The valve should never be lapped to the seat in the valve body.

g. Using a magnifying glass, inspect condition of seat in the valve body. If the seat is damaged or worn in any way to prevent proper seating of the valve, the nozzle assembly must be replaced. Examine the lapped bore in valve body for any signs of scoring. If scoring is apparent, the nozzle assembly must be replaced.

h. The outer surfaces of the valve body may be cleaned with a brass wire brush. Do not scrape carbon from the surface around the orifices in tip of valve body with any hard object as damage may result.

i. Clean the four orifices in the valve body tip. Refer to instructions in FUEL SYSTEM Topic, Section 1.

j. Visually inspect the condition of the valve, preferably with aid of a magnifying glass. The lapped surface (large O.D.) of the valve must be smooth and free of signs of scoring. Also, the valve must not show any wear or damage at seat location. If the valve is damaged in any way, the nozzle assembly must be replaced.

k. Thoroughly rinse the valve and valve body in clean diesel fuel or calibrating oil. The valve must fit freely in the valve body. To check this fit, lift valve about one third of its length out of the body. The valve should slide down to its seat without aid when assembly is held at a 45° angle.

If the fit of the valve in the valve body is unsatisfactory, the valve may be cleaned and polished with Allis-Chalmers 1000G lapping compound and castor oil used on tissue paper. The valve may be held by its stem in a revolving chuck for this cleaning operation. An orange stick or round toothpick will be helpful in cleaning the valve.

Hard or sharp tools, emery cloth, crocus cloth, jeweler's rouge, grinding compounds, or other abrasives should never be used in cleaning.

l. Thoroughly rinse the valve in clean diesel fuel before installing it in the valve body.

m. Examine the flat sealing surface of the valve body (surface which contacts lower end of the holder body) and make certain surface is clean and free of scratches. This surface may be lapped, if necessary, using Allis-Chalmers 1000G lapping compound, castor oil, and a lapping block as shown in Figure 3. After lapping, remove all traces of lapping compound with clean diesel fuel.

n. Make certain that the bottom flat sealing surface of the nozzle holder body is clean and in good condition. Rinse the valve and valve body in clean diesel fuel, then insert

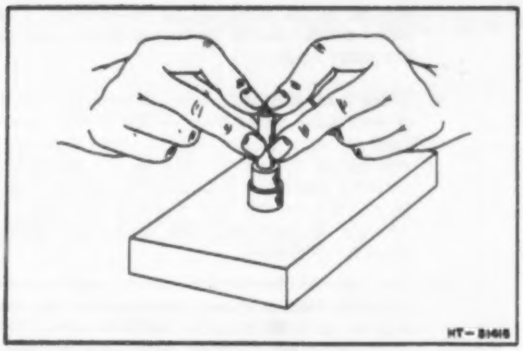


Figure 3. Lapping Fuel Injection Nozzle Valve Body

valve into position in the valve body. Place the valve body and valve in position on the end of the nozzle holder body and center the valve body with the holder body. Install and tighten the nut to a torque of 40 to 60 lbs. ft.

> NOTE: It is important that the valve body be centered in the nozzle retaining nut. Use care while tightening the nozzle retaining nut so that the valve body remains centered in the nut.

o. Test and adjust the fuel injection nozzle. Refer to FUEL SYSTEM Topic, Section 1.

2. Nozzle Holder Disassembly, Cleaning, and Assembly.

If malfunctioning of the fuel injection nozzle holder was not corrected by removal and cleaning of the nozzle valve body and valve, disassemble and clean the nozzle holder as follows:

a. Clamp nozzle holder assembly in a holding fixture similar to the one illustrated in Figure 2 and remove the cap nut and gasket from upper end of nozzle holder. Loosen and remove the pressure adjusting screw locknut and gasket.

b. Remove pressure adjusting screw, spindle spring, and spindle.

c. Remove nozzle retaining nut, nozzle valve body, and nozzle valve.

d. Place all parts in clean diesel fuel. Using filtered compressed air, blow out the fuel passages in the holder body.

e. Visually inspect the parts for damage or wear; replace necessary parts. Examine the flat sealing surface of holder body (surface which contacts upper end of valve body) and make certain the surface is clean and free from scratches. This surface should be lapped if necessary, using Allis-Chalmers 1000G lapping compound, castor oil, and a lapping block. When lapping use care to keep the nozzle holder body square with the lapping block to assure contact with the entire area being resurfaced. After lapping, remove all traces of the lapping compound with clean diesel fuel and dry with filtered compressed air.

f. Examine the spindle spring. If the spring is scratched or pitted, it must be replaced. Also, the spring must be replaced if the ends have worn. Always replace questionable springs.

g. Rinse spindle in clean fuel and insert it into holder body. Place the spindle spring in position on spindle. Install pressure adjusting screw, pressure adjusting screw locknut and gasket, cap nut and gasket - do not tighten at this time.

h. Install nozzle valve, valve body, and nozzle retaining nut. Tighten nut to a torque of 40 to 60 lbs. ft.

i. Test and adjust the fuel injection nozzle holder assembly as instructed in FUEL SYSTEM Topic, Section 1.

j. Tighten the cap nut to a torque of 75 to 90 lbs. ft.

k. Install the nozzle holder assembly as instructed in FUEL SYSTEM Topic, Section 1.

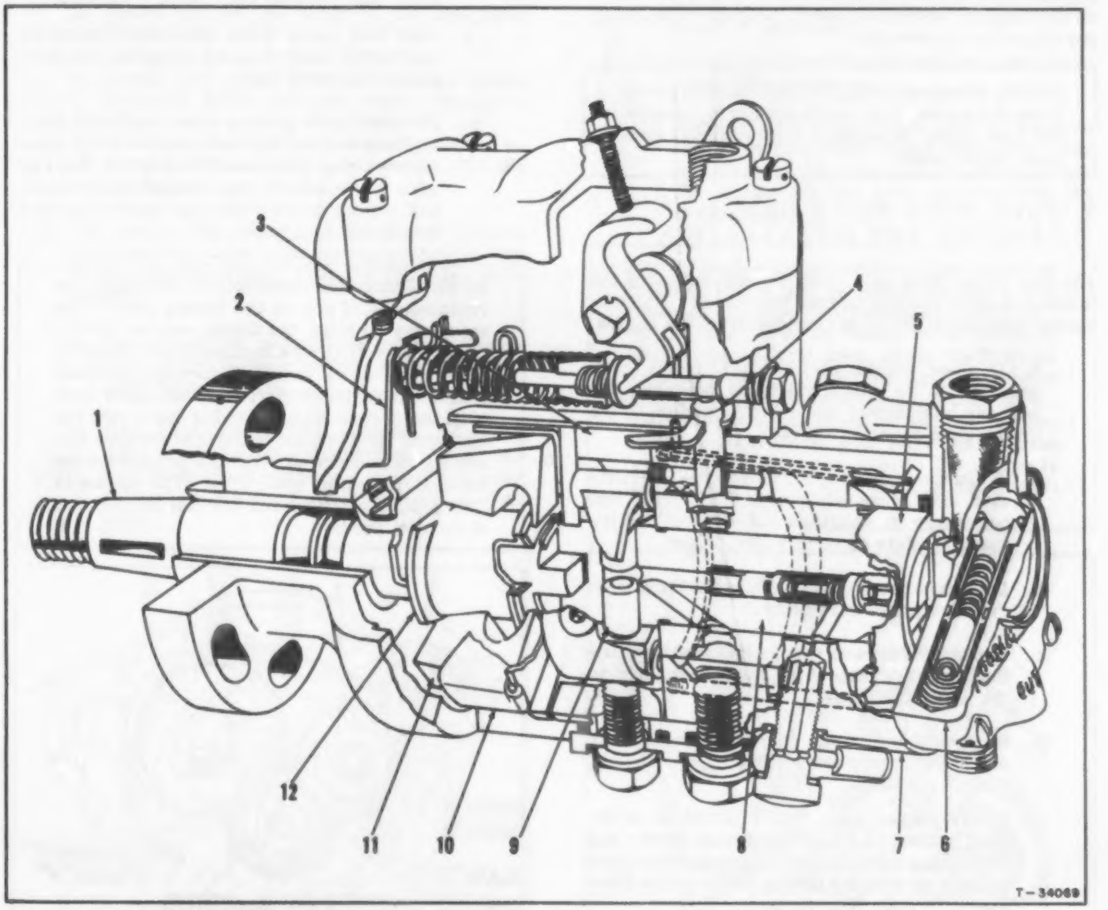
TOPIC 2. FUEL INJECTION PUMP AND GOVERNOR

A. GENERAL

The engine is equipped with a single cylinder, opposed plunger, inlet metering, distributor type fuel injection pump. The number of degrees before top dead center at which the fuel injection pump effects the injection of fuel into the cylinders is dependent upon engine application. The purpose of the fuel injection pump is to meter the fuel accurately and deliver it precisely at a definite moment in the engine cycle and under high pressure to the fuel injection nozzles.

An integral governor of the mechanical-centrifugal type controls fuel delivery and, therefore, engine speed. The governor is driven directly off of the pump drive shaft without gearing. The direction of rotation of the drive shaft is clockwise. The purpose of the governor is to serve as a means of pre-setting and maintaining, within close regulation, any desired engine speed within the nominal idling and maximum speed range, irrespective of engine load. The governor also controls the engine idling speed to prevent stalling, and the maximum speed to prevent racing.

For information concerning service, venting, fuel pump removal, installation, timing and adjustments, refer to FUEL SYSTEM Topic, in Section 1.



1. Drive Shaft
2. Governor Arm
3. Internal Cam Ring
4. Metering Valve
5. Transfer Pump
6. End Plate and Regulating Valve
7. Hydraulic Head
8. Distributor Rotor
9. Pumping Plungers
10. Weight Retainer
11. Governor
12. Sleeve

Figure 1. Fuel Injection Pump Main Components

TOPIC 3. FUEL INJECTION PUMP DRIVE GEAR, DRIVE SHAFT, AND MOUNTING ADAPTOR

A. GENERAL

The fuel pump drive gear is driven by the idler gear which in turn is driven by the crankshaft gear. The fuel pump drive gear is secured to the fuel pump drive shaft with a key, lockwasher and nut. The rear end of the pump drive shaft is splined to drive the fuel injection pump. The front end of the drive shaft contains a spring loaded thrust button.

A pump mounting adaptor is fitted to the rear of the front support plate and contains the bearing for the fuel pump drive shaft. The adaptor contains an oil passage and must be positioned with the scribed mark on its flange to the top so the oil passage is properly positioned to receive oil.

> NOTE: When removing the fuel injection pump from the engine, it is not necessary to remove the fuel pump mounting adaptor or the fuel pump drive shaft.

B. FUEL PUMP DRIVE GEAR REMOVAL AND INSTALLATION

The fuel pump drive gear may be removed thru the inspection plate opening or may be removed after the timing gear cover has been removed from the engine.

1. If for some reason only the fuel pump drive gear has to be removed and/or replaced, the gear can be removed through the opening in the timing gear cover as follows:

   a. Drain the cooling system; remove the radiator and components from the front end necessary to facilitate removal of the inspection plate on timing gear cover.

   b. Loosen capscrew and release the tension on the alternator drive belts.

   c. Remove capscrews and lockwashers securing inspection plate to gear cover and remove the inspection plate.

   d. Remove thrust button and spring from front end of fuel pump drive shaft.

   e. Rotate engine until No. 1 piston is at top dead center on its compression stroke and the timing mark on the fuel pump drive gear is lined up with the timing mark on the idler gear.

   f. Remove nut and lockwasher securing gear to fuel pump drive shaft.

   g. Remove the fuel injection pump from the fuel pump drive shaft. Refer to FUEL SYSTEM Topic, Section 1.

   h. Remove the two oil seals from the fuel pump drive shaft. Inspect oil seals for wear or damage. Replace if necessary.

   i. Withdraw the fuel pump drive shaft, with the drive gear attached, from the mounting adaptor and through the opening in the timing gear cover.

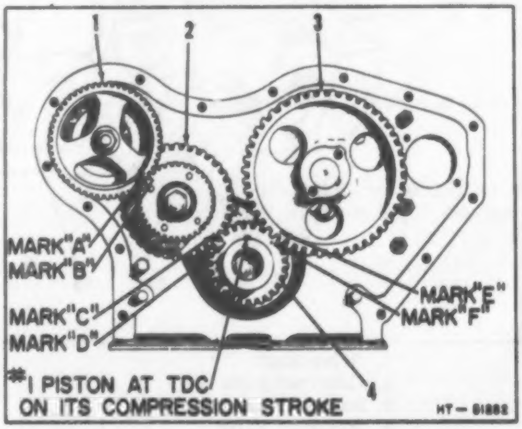
   j. Position fuel pump drive shaft and drive gear on a press and remove the fuel pump drive gear from the drive shaft. Inspect drive gear and replace if necessary.

   k. Before reinstalling, inspect fuel pump drive shaft and remove any burrs if necessary.

   l. Coat fuel pump drive shaft with engine oil and install shaft in pump mounting adaptor. Install woodruff key.

   m. Position drive gear on drive shaft with timing marks lined up between the drive gear and the idler gear, and the keyway lined up with the woodruff key. Install lockwasher and nut on drive shaft and tighten nut to a torque of 35 to 40 lbs. ft.

> NOTE: During the assembly of the engine or replacement of any of the timing gears it is necessary to align the timing marks "A-B", "C-D", and "E-F" as indicated in Figure 1. After aligning the marks, rotate the flywheel counterclockwise (view from timing gear end) until the proper degree timing mark (for the specified RPM) on the pulley and damper assembly is registered with the pointer on the front of the timing gear cover. The engine is now properly positioned for the installation of the fuel pump.



1. Fuel Pump Drive Gear
2. Idler Gear
3. Camshaft Gear
4. Crankshaft Gear

Figure 1. Timing Gear Marks

n. Install thrust button and spring in the front end of the fuel pump drive shaft.

o. Inspect inspection plate gasket and replace if necessary; cement gasket to inspection plate. Position inspection plate on gear cover, pressing against the thrust button, and secure with capscrews and lockwashers. Tighten capscrews to a torque of 28 to 33 lbs. ft.

> NOTE: The holes in the inspection plate are offset so the inspection plate can only be installed in one position.

p. Install the two oil seals on the fuel pump drive shaft.

q. Install and time the fuel injection pump. Refer to FUEL SYSTEM Topic, Section 1.

r. Complete the rest of the installation by reversing the removal procedure. Fill the cooling system.

2. To remove the fuel pump drive gear with an external gear puller, the timing gear cover has to be removed first. Use the following procedure:

a. Drain cooling system and remove timing gear cover. Refer to Section 8, FRONT END AND GEAR TRAIN.

b. Rotate engine until No. 1 piston is at top dead center on its compression stroke and the timing mark on the fuel pump drive gear is lined up with the timing mark on the idler gear.

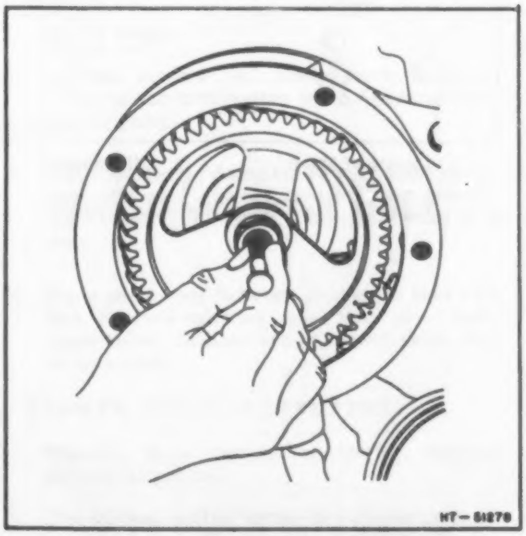


Figure 2. Installing Thrust Button and Spring in Fuel Pump Drive Shaft

c. Remove fuel pump drive gear retaining nut and lockwasher.

d. Install an external gear puller on the fuel pump drive gear similar to the one illustrated in Figure 3. Use a shaft protector between the screw on the gear puller and the end of the fuel pump drive shaft.

e. Remove the fuel pump drive gear and the woodruff key.

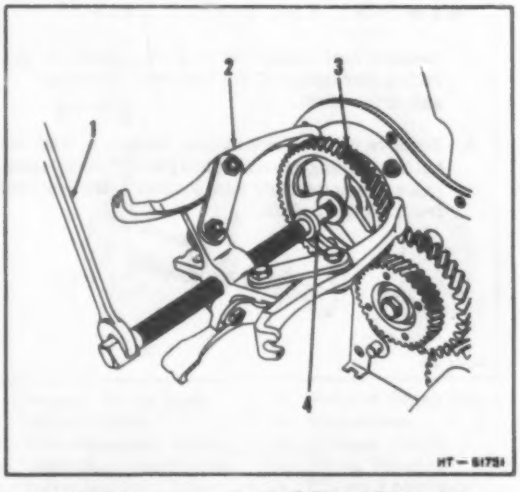
f. Inspect fuel pump drive gear and replace if gear is worn, scored, chipped, or has broken teeth.

g. Before installing fuel pump drive gear, inspect fuel pump drive shaft and remove any burrs if necessary.

h. Install woodruff key and coat fuel pump drive shaft with engine oil.

i. Position fuel pump drive gear on shaft so that the timing mark on the drive gear lines up with the timing mark on the idler gear and the keyway in the gear lines up with the woodruff key.

> NOTE: During the assembly of the engine or replacement of any of the timing gears it is necessary to align the timing marks "A-B", "C-D", and "E-F" as indicated in Figure 1. After aligning the marks, rotate the flywheel counterclockwise (view from timing gear end) until the proper degree timing mark (for the specified RPM) on the pulley and damper assembly is registered with the pointer on the front of the timing gear cover. The engine is now properly positioned for the installation of the fuel pump.



1. Wrench
2. Gear Puller
3. Fuel Pump Drive Gear
4. Shaft Protector

Figure 3. Removing Fuel Pump Drive Gear

j. Install the retaining nut and lockwasher and tighten nut to a torque of 35 to 40 lbs. ft.

k. Complete the rest of the installation by reversing the removal procedure described in the preceding steps.

C. FUEL PUMP DRIVE SHAFT REMOVAL AND INSTALLATION

1. Remove fuel injection pump. Refer to FUEL SYSTEM Topic, Section 1.

2. Remove fuel pump drive gear and woodruff key. Refer to Paragraph B of this Topic.

3. Remove fuel pump drive shaft by withdrawing it towards the rear of the engine and preventing damage to the oil seals on the shaft.

4. Inspect fuel pump drive shaft and replace if it is worn, scored, or nicked. The specified shaft diameter is .8735" to .874" and the specified bore in the bearing after being pressed into the mounting adaptor is .875" to .877". The specified shaft-to-bearing clearance is .001" to .0035".

5. Coat bearing diameter with engine oil and install fuel pump drive shaft with shaft seals in mounting adaptor.

6. Install woodruff key and fuel pump drive gear. Refer to Paragraph B of this Topic.

7. Install and time the fuel injection pump. Refer to FUEL SYSTEM Topic, Section 1.

8. Fill cooling system to the proper level.

D. FUEL PUMP MOUNTING ADAPTOR REMOVAL AND INSTALLATION

1. Remove fuel pump drive shaft. Refer to preceding Paragraph C for removal of components and drive shaft.

2. Remove nuts, lockwashers, washers, and lock bolts securing mounting adaptor to front support plate. Tap mounting adaptor and remove it from front support plate.

3. Clean and inspect fuel injection pump mounting adaptor. The specified bore of the bearing after it is pressed into the mounting adaptor is 0.875" to 0.877". Replace bearing if the bore is not within these tolerances.

CAUTION: Do not use cleaning solvents that are harmful to aluminum.

4. Install new O-ring in groove of fuel pump mounting adaptor.

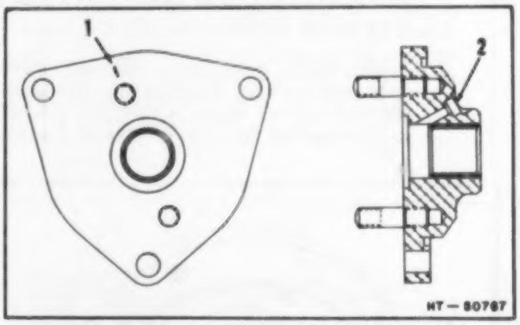
5. Position mounting adaptor in front support plate so that the scribed mark on the flange of the adaptor is up. The adaptor has an oil passage that must be to the top when installed. Refer to Figure 4. Tap mounting adaptor into place.

6. Secure mounting adaptor with lock bolts, seal washers, washers, lockwashers, and nuts. Tighten nuts to a torque of 18 to 21 lbs.ft. Use seal washers under the heads of the lock bolts. Seal washers added effective with S/N 3D02844.

7. Install fuel pump drive shaft into the mounting adaptor. Complete the rest of the front end installation. Refer to Paragraph C of this Topic.

8. Install and time the fuel injection pump. Refer to FUEL SYSTEM Topic, Section 1.

9. Fill cooling system to the proper level.



1. Scribed Mark 2. Oil Passage

Figure 4. Fuel Pump Mounting Adaptor

TOPIC 4. HAND PRIMER PUMP

A. GENERAL

The hand primer pump is of the plunger type and is connected between the fuel sediment bowl filter and fuel filter on the engine. It is used primarily for completely filling the fuel system before initial start-up, and after system has been opened for filter changing or servicing of the fuel injection system. Secondary function of the hand primer pump is to prevent fuel from draining out of the system while engine is not in operation.

The hand primer pump is operated as follows:

1. Unscrew plunger clamp screw and swing clamp wire off plunger.
2. Loosen vent plug on top of fuel filter head. Operate hand primer pump by alternately pulling the pushing plunger handle in and out of pump body several times to purge air from fuel filter.
3. When flow of fuel around vent plug is free of air bubbles, tighten vent plug securely. Operate pump plunger until solid pumping is encountered, indicating fuel has filled injection pump gallery.
4. Swing clamp wire up and tighten clamp screw on top of plunger.

B. REMOVAL AND DISASSEMBLY

1. Shut valve off at fuel tank. Disconnect fuel supply line at fuel sediment bowl filter.
2. Disconnect fuel line at hand primer pump outlet.
3. Remove fuel sediment bowl filter from hand primer pump.
4. Remove screws and lockwashers securing primer pump to mounting plate. Remove hand primer pump.
5. Unscrew plunger clamp screw and swing clamp wire off plunger. Spread wire to disengage ends. Remove plunger, guide, and piston seal as a unit.
6. Place pump body between protective jaws in a vise. Remove valve nut, seal ring, inner seal, upper valve, retainer spring, lower valve, and valve gasket.

C. PRIMER PUMP INSPECTION

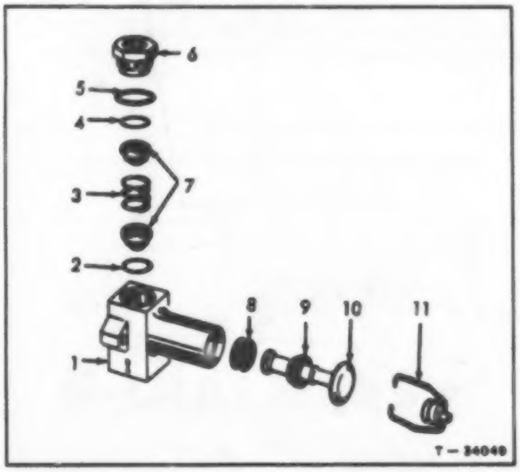
1. Examine valve gaskets for defects. Replace gaskets as needed.
2. Check piston seal on bottom of plunger for damage and replace if necessary. Check for foreign material in valves and hand primer pump body.
3. If rubber plunger guide is worn, cut and remove it. Using clean grease for lubricant, slip new guide, chamfer side down, over end of plunger.

D. PRIMER PUMP ASSEMBLY AND INSTALLATION

1. Assemble valve gasket, lower valve, retainer spring, upper valve, inner seal, seal ring, and valve nut in primer pump body.
2. Assemble piston seal, plunger guide and pump plunger in primer pump body.

CAUTION: Check action of hand primer pump to make certain valves open in direction indicated by arrow on pump body.

3. Spread clamp wire to fully engage guide slots, swing wire up and tighten clamp screw.
4. Secure hand primer pump to mounting plate with screws and lockwashers.
5. Clean glass sediment bowl. Install fuel sediment bowl filter adjacent to hand primer pump.
6. Connect fuel supply lines to sediment bowl filter and to hand primer pump.
7. Open fuel tank shutoff valve and vent the fuel system. Refer to FUEL SYSTEM Topic, Section 1.



1. Primer Pump Body
2. Valve Gasket
3. Valve Retainer Spring
4. Valve Nut (Inner) Seal
5. Valve Nut Seal Ring
6. Valve Nut
7. Primer Pump Valve
8. Piston Seal
9. Plunger Guide
10. Pump Plunger
11. Clamp Assembly

Figure 1. Hand Primer Pump Details

SECTION 5
INTAKE MANIFOLD

TOPIC	TITLE	
1	INTAKE MANIFOLD . . . . A. INTAKE MANIFOLD REMOVAL B. INTAKE MANIFOLD INSPECTION C. INTAKE MANIFOLD INSTALLATION	5.1

5

TOPIC 1. INTAKE MANIFOLD

The air intake system consists of those components which convey filtered air to the engine cylinders.

The intake system consists of the air cleaner (refer to AIR CLEANER Topic, in Section 1) and intake manifold. If the engine is equipped with a turbocharger, the compressor side of the turbocharger is part of the intake system.

It is important to provide an ample supply of fresh air to the combustion chambers. Insufficient air will limit the amount of fuel the engine can burn and will lead to loss of power, excessive exhaust smoke, and high fuel consumption. Contaminated air leads to worn engine parts, high oil consumption, and eventual engine failure.

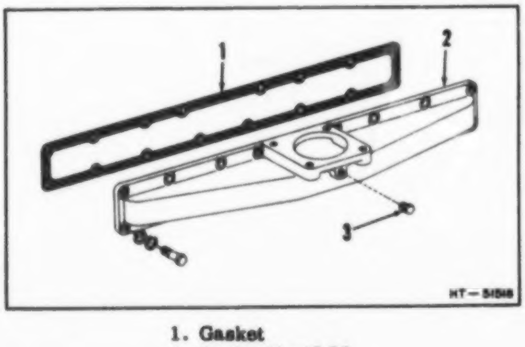
The intake manifold is sealed to the cylinder head with a one piece gasket and secured in place with capscrews, lockwashers, and washers.

A. INTAKE MANIFOLD REMOVAL

The intake manifold can be removed from or installed on the engine in or out of the unit. To remove the intake manifold from the engine, follow the procedure outlined below:

1. Remove capscrew, lockwasher, and washer securing breather tube upper clamp. Remove capscrew, lockwasher, and nut securing breather tube lower clamp. Loosen hose clamp and remove breather tube.
2. Disconnect cable from air heater element. Carefully remove air heater element and gasket from intake manifold flange or from turbocharger air outlet elbow, depending upon the application.

NOTE: For inspection of air heater element, refer to ELECTRICAL SYSTEM Topic, in Section 1.

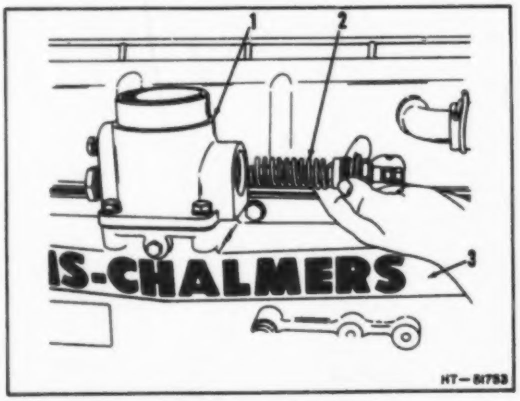


1. Gasket
2. Intake Manifold
3. Plug

Figure 1. Intake Manifold and Gasket

3. Remove air cleaner from intake manifold flange. Remove capscrews and lockwashers securing intake manifold flange and remove flange and gasket. If applicable, also remove tachometer clamp.

   If engine is equipped with a turbocharger, remove capscrews, lockwashers, and washers securing turbocharger air outlet elbow to top of intake manifold. Loosen hose clamp and remove air outlet elbow and gasket. Remove tachometer cable clamp if so equipped.
4. If engine is equipped with an engine mounted instrument panel, remove capscrews and lockwashers securing instrument panel brackets to cylinder block. Carefully move instrument panel (with wiring intact) to one side to the rear to facilitate removal of capscrew securing intake manifold to cylinder head.
5. If engine is equipped with a coolant filter remove capscrews and lockwashers securing coolant filter mounting bracket to engine. Remove bracket with coolant filter (hoses intact) and allow them to hang to one side.
6. If engine is a Model 3500 and is equipped with an air cleaner, remove air cleaner in order to remove air cleaner mounting bracket. Remove capscrews, washers, lockwashers, and nuts securing bracket to brace on cylinder head. Then remove capscrews and lockwashers securing bracket to intake manifold and remove air cleaner mounting bracket.
7. Remove remaining capscrews, washers, and lockwashers, securing intake manifold to cylinder head; remove intake manifold and manifold gasket.



1. Intake Manifold Flange
2. Air Heater Element
3. Intake Manifold

Figure 2. Removing Air Heater Element

B. INTAKE MANIFOLD INSPECTION

1. Wash and clean intake manifold with kerosene or trichlorethylene.

> CAUTION: Trichlorethylene solvent is toxic and very volatile. Use only in a well ventilated room or area. Do not inhale fumes for an extended length of time. Do not use cleaning solutions that are harmful to aluminum.

2. Check manifold for foreign deposits, clean and remove obstructions found within the manifold.

3. If manifold is cracked, it must be repaired or replaced.

4. If the mounting surface of the intake manifold is warped enough so that it will not seal, the manifold must be replaced.

5. **Inspect and clean the mounting surface on the cylinder head to make certain it is free of gasket particles or foreign matter.**

C. INTAKE MANIFOLD INSTALLATION

1. **Install the intake manifold to the engine by a direct reversal of the removal procedure.**

2. **Always use a new gasket when installing the intake manifold.**

3. **Torque the intake manifold securing capscrews to 28 to 33 lbs. ft.**

4. **After the engine is run and the water temperature reaches approximately 170°F., again torque the capscrews to the above value.**

SECTION 6
EXHAUST MANIFOLD AND TURBOCHARGER

TOPIC	TITLE	
1	EXHAUST MANIFOLD	6.1
	A. GENERAL B. EXHAUST MANIFOLD REMOVAL C. EXHAUST MANIFOLD INSPECTION D. EXHAUST MANIFOLD INSTALLATION	
2	TURBOCHARGER	6.2
	A. GENERAL B. 2000 HOUR INSPECTION AND SERVICE C. INSTALLATION OF COMPRESSOR AND BEARING HOUSING D. MAINTENANCE E. REMOVAL AND INSTALLATION F. DISASSEMBLY, CLEANING, INSPECTION AND REASSEMBLY G. TROUBLESHOOTING H. TOOLS	

TOPIC 1. EXHAUST MANIFOLD

A. GENERAL

The exhaust system consists of those components which convey the exhaust gases to the atmosphere. The exhaust system consists of the exhaust valves, exhaust manifold, muffler, and exhaust piping. If the engine is equipped with a turbocharger, the turbine of the turbocharger is part of the exhaust system.

The exhaust manifolds are of two types; one is for naturally aspirated engines and the other is for turbocharged engines. Both of the manifolds are manufactured from alloy cast iron. The naturally aspirated engine exhaust manifold is of a one piece construction, whereas the exhaust manifold on a turbocharged engine is in three sections with the front and the rear sections inserted into the center section. The manifolds are sealed to the exhaust parts of the cylinder head with steel-asbestos gaskets and secured in place with capscrews and lock washers.

B. EXHAUST MANIFOLD REMOVAL

The exhaust manifold can be removed from or installed on the engine in or out of the unit. To remove the exhaust manifold from the engine use the following procedure:

1. If engine is in a closed power unit remove the side door on the right side of the unit.
2. Remove the exhaust pipe from the exhaust manifold or the diffuser elbow, depending upon the application.
3. If engine is equipped with a turbocharger, remove the turbocharger (refer to Topic 2 in this Section).
4. Remove capscrews and lockwashers securing exhaust manifold to the cylinder head and remove the exhaust manifold.

NOTE: If engine is equipped with a turbocharger, remove exhaust manifold as an assembly.

5. Separate turbocharged engine exhaust manifold for inspection.

C. EXHAUST MANIFOLD INSPECTION

1. Wash and clean exhaust manifold with a cleaning solvent.
2. Check manifold for carbon deposits; clean and remove obstructions found within the manifold.
3. If manifold is cracked, repair or replace it.
4. If mounting surfaces of the manifold are warped enough so that they will not seal, the manifold must be machined or replaced.

Figure 1. Not applicable.

NOTE: On the three piece exhaust manifold, if one section is machined, the same amount must be removed from the other two sections.

5. Inspect and clean the mounting surface on the cylinder head to make certain it is free of gasket particles or foreign matter.

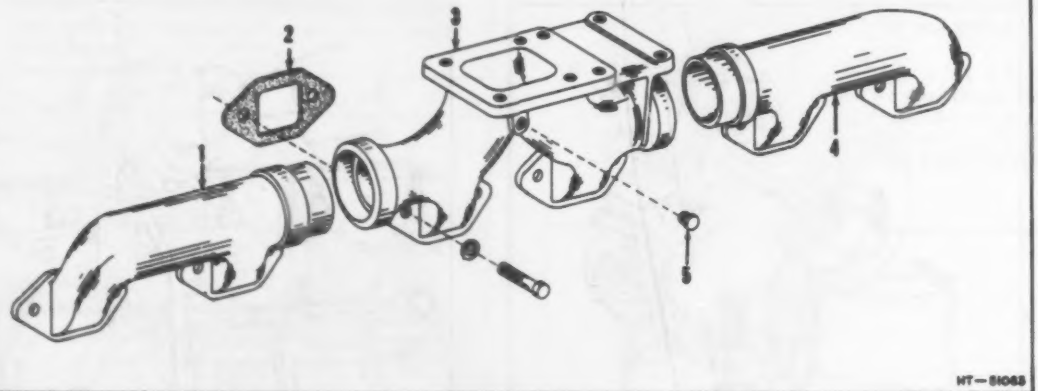
D. EXHAUST MANIFOLD INSTALLATION

The installation of the exhaust manifold to the cylinder head is a direct reversal of the removal procedure as outlined in preceding Paragraph B.

Always use new gaskets when installing the exhaust manifold and mounting the turbocharger (when so equipped). Cement the gaskets to the exhaust manifold and let them dry. Use two temporary guide studs in the cylinder head when installing the exhaust manifold. The temporary studs are removed after the capscrews and washers are installed.

NOTE: Install the center section of the three piece manifold first, using two temporary studs in the cylinder head. The temporary studs are removed after the capscrews are installed.

Tighten the exhaust manifold capscrews to a torque 68 to 73 lbs. ft. After the engine is operating and the water temperature reaches approximately 170°F., again torque the capscrews to the specified torque.



1. Rear Section
2. Gasket
3. Center Section
4. Front Section
5. Plug

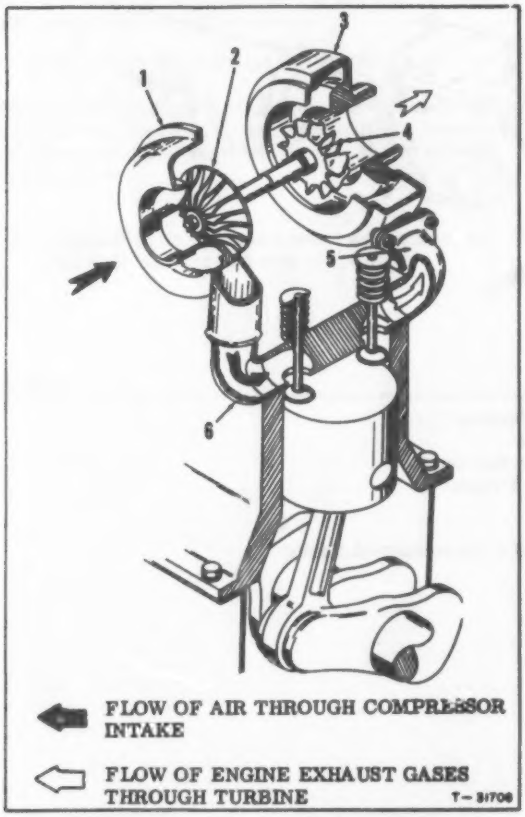
Figure 2. Exhaust Manifold - Turbocharged Engine

TOPIC 2. TURBOCHARGER

A. GENERAL

The overhaul information contained within this Section is supplemental to the service information given in TURBOCHARGER Topic, Section 1.

A turbocharger is used to boost the power output of an engine over that of naturally aspirated engines by increasing the supply of air to the cylinders. The "Thompson" Turbocharger is a highly efficient, yet rugged and easy to install, exhaust-driven blower. The simple, compact design of the turbocharger incorporates a single stage radial inflow turbine wheel, mounted on a common shaft with a single stage centrufugal compressor impeller. It has a one-piece bearing housing with semi-floating sleeve type bearing, a turbine housing, and a compressor housing. Both the turbine wheel and compressor impeller are individually precision balanced. Split-ring seals prevent oil leakage at the shaft ends.


1
2
3
4
5
6
⬅ FLOW OF AIR THROUGH COMPRESSOR INTAKE
⇦ FLOW OF ENGINE EXHAUST GASES THROUGH TURBINE
T-31706

1. Compressor
2. Impeller
3. Turbine
4. Turbine Wheel
5. Exhaust Manifold
6. Intake Manifold

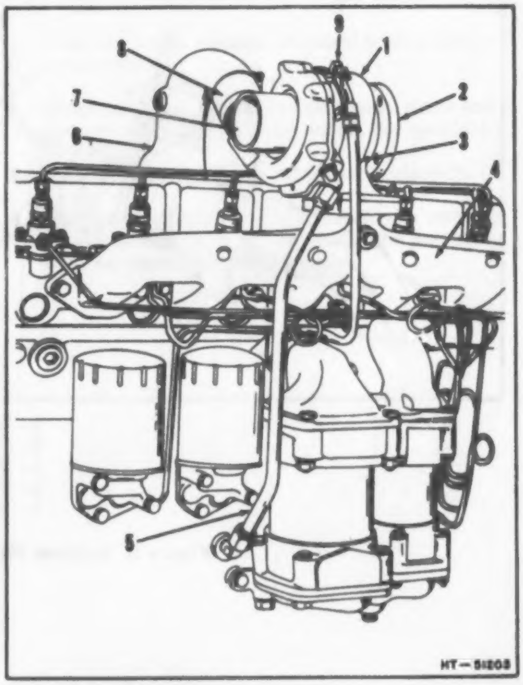
Figure 1. Turbocharger Operation Diagram

B. 2000 HOUR INSPECTION AND SERVICE

Perform a major inspection of the turbocharger after each 2000-hour interval of operation. This inspection is made by disconnecting turbocharger compressor and bearing housing from turbine housing, allowing the turbine housing to remain in place on exhaust manifold mounting pad.

> CAUTION: Clean entire turbocharger assembly including air piping and oil lines with cleaning solvent. This precaution is necessary to prevent entrance of foreign material into the engine and turbocharger system during disassembly.

Inspect and service the turbocharger as follows (Figure 2):



1. Turbocharger
2. Exhaust outlet
3. Oil inlet line
4. Exhaust manifold
5. Oil return line
6. Turbocharger-to-intake manifold elbow
7. Turbocharger compressor housing inlet
8. Intake manifold-to-compressor housing hose
9. Turbine housing clamp

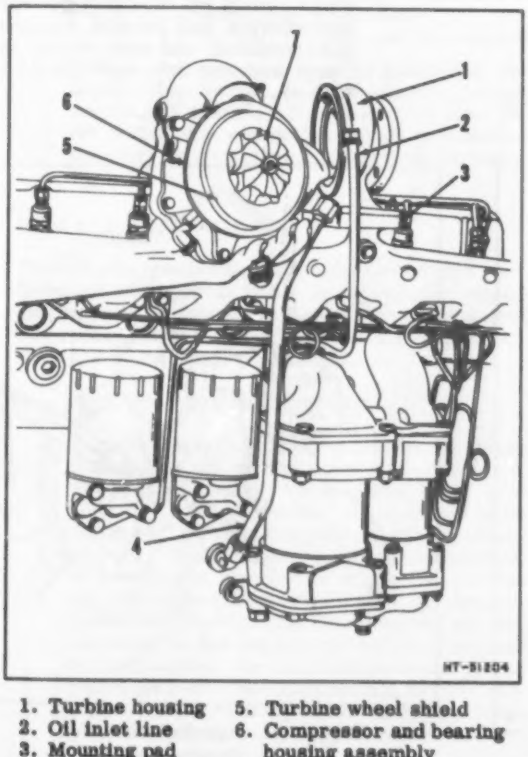
Figure 2. Typical Turbocharger Installation

1. Remove air cleaner piping from the turbocharger compressor housing inlet. Observe condition of impeller and housing. Dirt accumulation will disturb precision balance of the rotating assembly and cause turbocharger malfunction.
2. Disconnect oil lines (3) (5) from turbocharger. Cover all openings to prevent entrance of foreign material. Loosen hose clamps and remove hose (8). Support the compressor and bearing housing and remove clamp (9).

NOTE: It may be necessary to rotate the clamp to facilitate removal.

3. Remove housing Figure 3 (6) as an assembly from turbine housing.

CAUTION: Use extreme care to prevent damage to moving parts of the turbocharger. Avoid rough handling. Do not rest the assembly on the turbine blades. Take care to prevent entry of dirt and dust into the turbocharger, and observe all precautions consistent with the handling of precision built machinery.



1. Turbine housing
2. Oil inlet line
3. Mounting pad
4. Oil return line
5. Turbine wheel shield
6. Compressor and bearing housing assembly
7. Turbine wheel

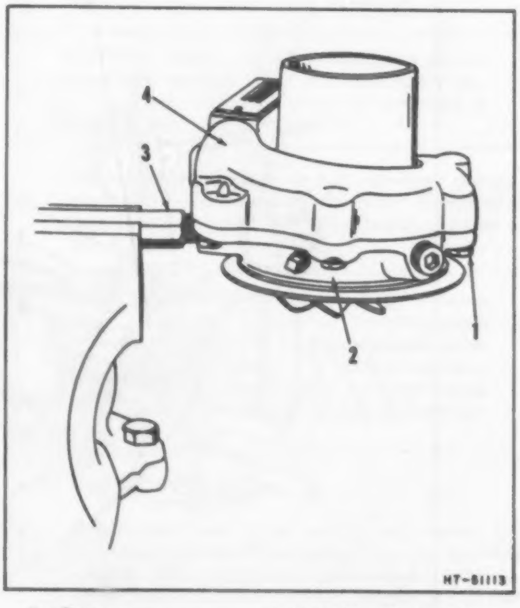
Figure 3. Compressor and Bearing Housing Removal

4. Inspect turbine wheel for cracks, erosion, nicked or bent blade tips, and broken or missing blades. Inspect turbine wheel shield for warpage, rubbing, scoring, and erosion. Check for carbon accumulations behind turbine wheel. Check for free rotation of the turbine wheel and impeller.

NOTE: During check for free rotation, the shield must be depressed against spring-ring tension.

If turbine wheel and impeller do not rotate freely, the parts may be damaged, or foreign material may be causing friction, in which case further disassembly and inspection is necessary. If no damage or undue friction is detected, clean the unit and check end play and radial play as directed below.

5. Install mounting fixture, Figure 28, (1) (9) in one of bearing housing oil drain holes and clamp in a vise as shown in Figure 4. Remove 6 capscrews (1) securing housing (4) to bearing housing (2), and remove housing (4) and gasket.
6. Thoroughly clean the assembly using a nylon bristle brush and a solvent such as diesel fuel or kerosene to remove accumulated dirt. Failure to remove all dirt may result in a more unbalanced condition than that which existed before cleaning.



1. Capscrew
2. Bearing housing
3. Mounting fixture
4. Compressor housing

Figure 4. Preparing to Separate Compressor Housing from Bearing Housing

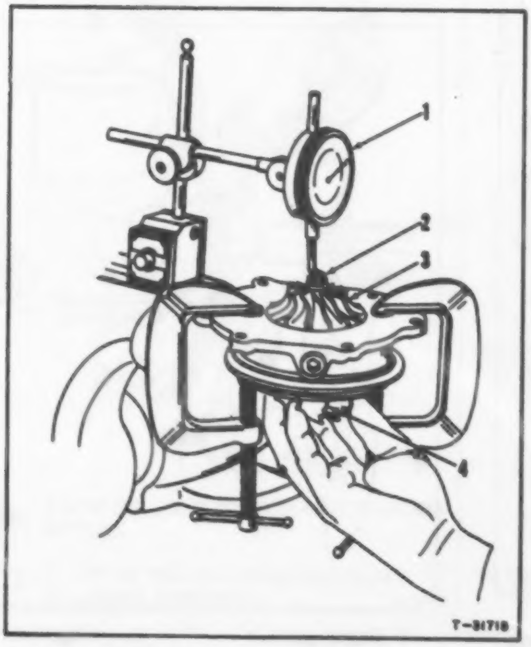
CAUTION: Never use caustic solution or other cleaner that will attack metal. Never use a wire brush that will score highly finished parts.

7. Use C-clamps, Figure 5, to overcome spring-ring tension and hold turbine shield against bearing housing.

8. Attach a dial indicator to bearing housing so contact point is resting on a flat surface of the impeller nut. Push up on turbine wheel, Figure 5, and measure shaft end play. Maximum allowable shaft end play is .009". If shaft end play is excessive, turbocharger must be rebuilt.

9. Reposition dial indicator so contact point is resting on a flat side surface of the impeller nut and adjust pointer to zero. Push impeller from side to side, Figure 6, to determine shaft radial play. Rotate the shaft slightly to get maximum readings on the nut flat. Maximum allowable radial play is .022". If radial play is excessive, parts are worn and turbocharger must be rebuilt.

10. Remove the dial indicator and C-clamps.



1. Dial indicator
2. Impeller nut
3. Impeller
4. Turbine wheel

Figure 5. Measuring Total Shaft End Play

11. If the unit is in satisfactory condition, position housing, Figure 4 (4), and new gasket on housing (2). Secure with capscrews (1). Tighten capscrews evenly and alternately to 80-100 lbs. in torque.

CAUTION: Excessive tightening will strip the housing threads.

C. INSTALLATION OF COMPRESSOR AND BEARING HOUSING

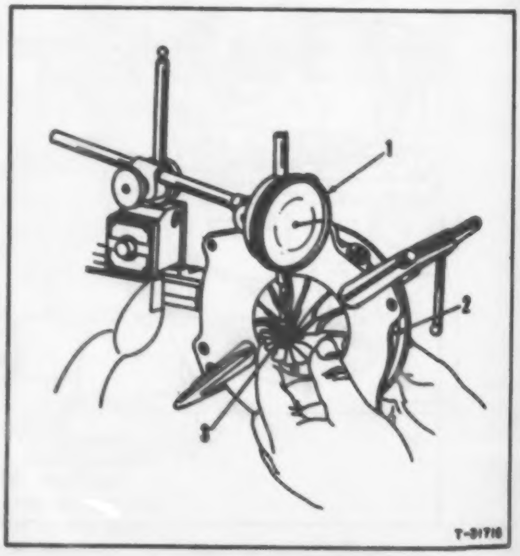
1. Complete the following steps before assembling turbocharger to engine:

   a. Service air cleaner as detailed in the applicable operators manual.

   b. Inspect hose or tubing connections between air cleaner and turbocharger air inlet for restrictions and deterioration. Clean or replace if necessary.

   c. Inspect turbocharger-to-intake manifold elbow for restrictions and inspect hose connection for deterioration. Clean or replace if necessary.

   d. Make certain the mounting gasket between turbocharger and exhaust manifold is in good condition, and make certain mounting flange locknuts are tight (18-21 lbs. ft. torque).



1. Dial indicator
2. Bearing housing
3. Impeller nut

Figure 6. Measuring Shaft Radial Play

e. Make certain the gasket between intake manifold and turbocharger-to-intake manifold elbow is in good condition.

f. Inspect oil supply and return lines to ensure they are not clogged or dented, thereby restricting oil flow.

g. Inspect engine breather system and clean if necessary.

2. Using a new turbine housing gasket, position housing assembly, Figure 3 (6), on the turbine housing. Position clamp, Figure 2 (9), but do not tighten. Align compressor housing air outlet with hose (8). Tighten turbine housing clamp nut to 5-10 lbs. in. torque. Tighten hose connector clamps on elbow and compressor housing air outlet opening.

3. Install hose or tubing from air cleaner to compressor housing inlet.

4. Install exhaust piping if it was removed.

5. Connect oil inlet line (3) to the turbocharger.

CAUTION: Do not connect the oil return line to the turbocharger until a free flow of oil through the turbocharger is assured.

6. With the key switch in the OFF position or the engine stop control in STOP position, crank engine until there is a free flow of oil from the oil return line connection in bottom of turbocharger. Connect oil return line (5) to the bearing housing.

D. MAINTENANCE

The turbocharger is often blamed for poor engine performance when actual cause is lack of good engine maintenance. Satisfactory turbocharger life requires that special attention be given the following adjustment and maintenance procedures.

1. Air Cleaner and Intake System

Restrictions in the air intake system will cause malfunction of turbocharger and engine. A clogged air cleaner, deteriorated hose, or a collapsed hose connection can cause oil to be pulled past seals on compressor side of turbocharger. Restrictions in air intake system, with resultant transfer of engine oil to intake air, will cause increased exhaust temperatures. An excessively high exhaust temperature is detrimental to the engine, as well as to turbocharger turbine wheel and turbine housing, and will cause the turbine shaft bearing to overheat. If cause of overheating is not corrected, complete turbocharger failure will result.

An air leak caused by a loose hose clamp or a faulty gasket, will allow dirt to enter the air intake system. If oil has previously been drawn into the turbocharger compressor housing, incoming dirt will adhere to the oil and accumulate on impeller and inner housing surfaces, causing a reduction in volume of air drawn into the engine. When not distributed evenly on impeller, an accumulation of dirt will cause an unbalanced condition of rotating parts.

2. Lubrication

Engine lubricating oil and filter elements must be replaced at specified intervals to assure a clean supply of oil to the turbocharger. Many turbochargers have been damaged because operators extended recommended oil and filter change interval, or did not shorten interval to compensate for adverse operating conditions.

Regular inspections of the lubrication system are required to ensure that all connections are tight and that oil flow is not restricted by clogged or dented supply and return lines.

Loss of engine oil pressure because of worn engine bearings, oil pump failure, a clogged oil inlet line, or a restricted oil return line, will quickly damage the turbocharger. Minimum hot engine oil pressure for satisfactory turbocharger lubrication is 25 psi at rated engine speed and 10 psi at idle speed.

3. Exhaust System

If the engine is operated for an extended period of time with exhaust temperatures in excess of design limitations, both engine and turbocharger will be seriously damaged.

CAUTION: Under no circumstances should the factory maximum fuel delivery specification for the fuel injection pump be exceeded to obtain an increase in power.

The resulting damage to turbocharger and engine will be costly and offset any benefit that might have been derived by increasing power of the engine.

CAUTION: Total restriction of the exhaust system must not exceed 1" mercury back pressure at the turbine housing exhaust outlet under engine full-speed, full-load conditions. Excessive back pressure will reduce turbine speed and subject turbine to excessive temperatures.

4. Fuel Injection System

Insufficient fuel to the engine will cause low turbocharger speed and lack of power. For this reason, fuel filters and nozzle and holder assemblies should be serviced regularly. If fuel injection pump maximum fuel delivery rate is suspected of being incorrect, remove pump from engine and take it to an Allis-Chalmers dealer for checking on an injection pump test stand.

5. Engine Breather System

A clogged engine breather tube will cause pressure buildup in the engine. This pressure will prevent oil from draining down the return line and will force it out low pressure side of turbocharger and into engine air intake system.

E. REMOVAL AND INSTALLATION

The turbocharger is removed from the engine for 2000-hour inspection, for overhaul, and for unscheduled repair. When turbocharger is removed for 2000-hour inspection it is usually disconnected from the turbine housing and the housing allowed to remain in place on exhaust manifold mounting pad. For bench repair or overhaul, turbocharger must be removed from the engine as a complete assembly.

1. Removal (Figure 2)

   a. Remove hose or tubing from air cleaner outlet to inlet (7).

   b. Remove exhaust pipe, exhaust elbow, and diffuser from outlet (2).

   c. Disconnect and remove oil inlet line (3).

   d. Disconnect and remove oil return line (5).

   e. Loosen hose (8).

   f. Loosen and remove high temperature self-locking nuts securing turbocharger mounting flange to exhaust manifold mounting pad.

   g. Remove turbocharger from mounting pad.

2. Turbocharger Installation

   a. Before installing turbocharger, inspect/service the following:

   (1) Service air cleaner.

   (2) Replace engine lubricating oil filter elements. Change engine lubricating oil in crankcase.

   (3) Check exhaust manifold for cracks and foreign material. Check condition of manifold mounting gaskets, tightness of manifold nuts, and for flatness of the turbocharger exhaust manifold mounting pad.

   (4) Check intake manifold and turbocharger to intake manifold elbow for cracks and foreign material. Check condition of manifold mounting gaskets and for tightness of manifold nuts.

   (5) Make certain all hose connector clamps are tight.

CAUTION: Make certain the gaskets do not extend into port openings of the intake manifold, exhaust manifold, air elbow, and mounting pads.

   b. Place the asbestos-packed, steel-wrapped gasket on the exhaust manifold pad. Mount turbocharger on manifold mounting pad. Lubricate mounting studs with a high temperature thread lubricant. Tighten locknuts to 18-21 lbs. ft. torque.

   c. Loosen turbine housing clamp, Figure 2 (9), and rotate compressor outlet to the angular position required for lineup with elbow (6). Tighten turbine housing clamp nut to 5-10 lbs. in. torque. Tighten hose (8).

   d. Connect air cleaner to compressor inlet hose or tubing.

   e. Lubricate exhaust diffuser retaining capscrews with a high temperature thread lubricant. Position diffuser gasket between diffuser and turbine housing. Secure with capscrews and tighten to 28-33 lbs. ft. torque.

   f. Assemble diffuser ring and diffuser elbow to the turbocharger diffuser.

   g. Connect oil inlet line (3) to the turbocharger.

CAUTION: Do not connect the oil return line until a free flow of oil through the turbocharger is assured. Place engine stop control in stop position. Crank engine until there is free flow of oil from the oil return line connection in the bottom of the turbocharger.

   h. Connect oil return line (5) to turbocharger and to side of engine.

   i. Upon completion of installation, check turbocharger operation. (Refer to Paragraph D, TURBOCHARGER Topic, in Section 1.

CAUTION: Never operate engine while air intake lines or exhaust outlet pipe is disconnected. Clothing and other impeller damaging objects can be drawn into compressor side, while discharged carbon particles and hot exhaust gases can cause personal injury on turbine side.

F. DISASSEMBLY, CLEANING, INSPECTION AND REASSEMBLY

1. General

Disassembly of the turbocharger can best be accomplished with the aid of the service tools listed in Paragraph H.

As parts are removed, place them on a clean work bench in the order of disassembly, Figure 7. Care must be taken to prevent damage to components while they are on work bench.

To simplify alignment during reassembly, mark turbine and compressor housings before starting disassembly.

2. Disassembly

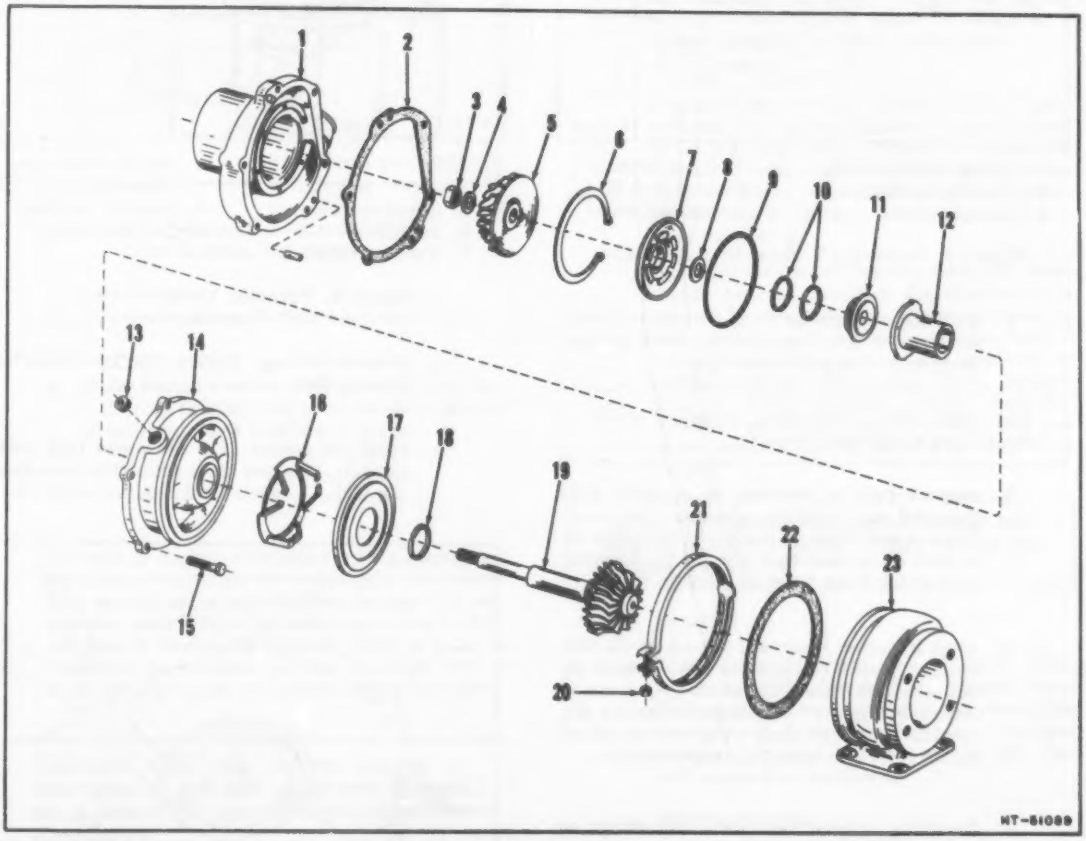
   a. Remove turbocharger assembly from the engine.

   b. Screw a 1/2" x 3/8" pipe bushing, Figure 28 (9), on the mounting fixture (1). Screw mounting fixture into oil drain line hole of bearing housing. Clamp mounting fixture in a bench vise so turbocharger compressor and bearing housing are positioned as shown in Figure 8.

   c. Remove clamp locknut and clamp securing turbine housing, Figure 8 (4), to bearing housing (2). Remove housing (4) and gasket.

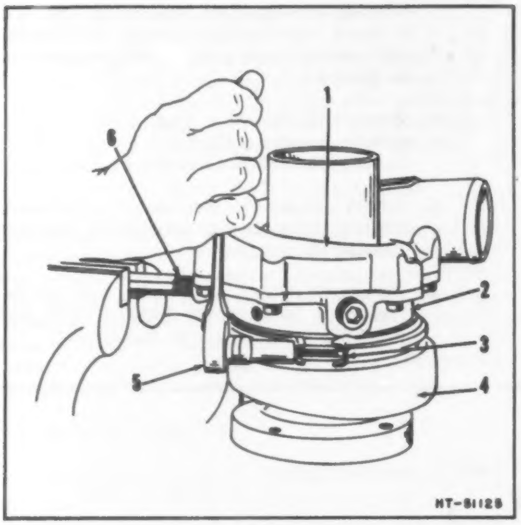
   d. Remove capscrews that secure compressor housing (1) to bearing housing (2). Remove housing (1) and gasket.

   e. Check and record shaft radial and end play (refer to 2000 HOUR INSPECTION AND SERVICE, Paragraph B, this Topic).



1. Compressor housing and groove pin
2. Compressor housing gasket
3. Impeller retaining nut
4. Impeller retaining washer
5. Impeller
6. Bearing retaining snap-ring
7. Oil retainer plate
8. Impeller shim
9. Oil retainer plate O-ring
10. Turbine shaft seals
11. Turbine shaft spacer
12. Turbine shaft bearing
13. Bearing housing pipe plug
14. Bearing housing
15. Compressor housing capscrew
16. Turbine wheel shield spring ring
17. Turbine wheel shield
18. Turbine shaft seal
19. Turbine wheel and shaft
20. Turbine housing clamp nut
21. Turbine housing clamp
22. Turbine housing gasket
23. Turbine housing

Figure 7. Turbocharger Details



1. Compressor housing
2. Bearing housing
3. Clamp screw
4. Turbine housing
5. Ratchet & socket
6. Mounting fixture

Figure 8. Removing Turbine Housing Clamp

f. Hold turbine blades with a cloth or V-belt and remove nut, Figure 7 (3), from turbine shaft end. Remove washer (4).

> CAUTION: The self-locking impeller shaft nut (3) has a left-hand thread.

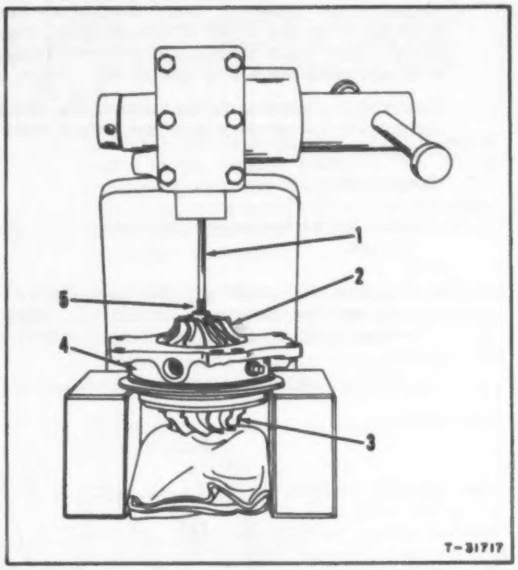
g. Support bearing housing in a press with threaded end of turbine shaft up, Figure 9. Place a soft cloth on the press bed plate so turbine wheel and shaft will not be damaged as it drops from bearing housing.

h. Align impeller remover, Figure 28 (2) with shaft, Figure 9 (5), end and press wheel (3) and shaft (5) from impeller (2). Remove impeller, Figure 7 (5), impeller shims (8), turbine wheel and shaft (19), turbine wheel shield (17), and shield spring-ring (16).

i. Carefully spread seal (18) just enough to remove it from shaft (19).

j. Remove snap-ring (2) as shown in Figure 10.

k. Turn housing, Figure 10 (4), over and position it on blocks in a press so the plate (3) can be pressed out. Use oil retainer plate remover, Figure 28 (3) to press plate and spacer from bearing housing as shown in Figure 11.

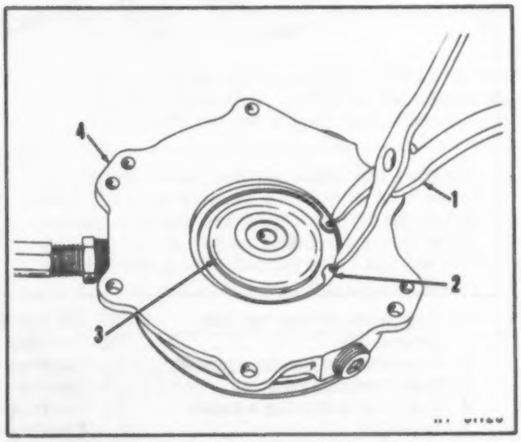


1. Impeller remover
2. Impeller
3. Turbine wheel
4. Bearing housing
5. Turbine shaft

Figure 9. Pressing Turbine Wheel and Shaft from Impeller

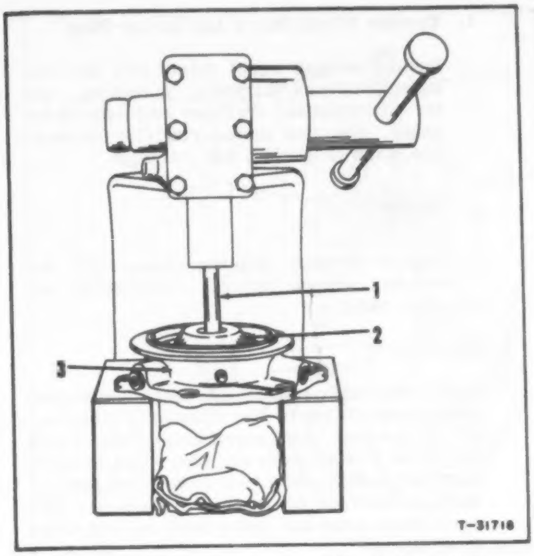
l. Remove O-ring, Figure 7 (9) from bearing housing (14).

m. Push out spacer (11) and seals (10) from plate (7). Remove the 2 seals (10) from spacer (11).



1. Snap-ring pliers
2. Bearing retaining snap-ring
3. Oil retainer plate
4. Bearing housing

Figure 10. Removing Bearing Retaining Snap-Ring



1. Oil retainer plate remover
2. Oil retainer plate
3. Bearing housing

Figure 11. Pressing Oil Retainer Plate from Bearing Housing

n. Remove bearing (12) from housing (14).

o. Unscrew and remove 2 remaining pipe plugs (13) from housing (14) to facilitate cleaning of housing. Note location of plugs.

3. Cleaning And Inspection

At time of engine overhaul it is recommended that the turbocharger be completely disassembled and all parts inspected for damage and excessive wear. Wash turbocharger parts in diesel fuel or kerosene, allowing them to soak as required to remove carbon deposits. Use a nylon bristle brush to remove heavy deposits.

CAUTION: Never use caustic solution or other cleaner that will attack metal. Never use a wire brush that will score highly finished parts.

Repair minor surface damage to highly finished metal parts by burnishing or polishing. Use silicon carbide abrasive cloth on aluminum parts and crocus cloth on steel parts.

When rebuilding turbocharger, replace all gaskets, shaft seals, and O-ring with new parts.

Refer to Figure 7 and inspect individual par as follows:

a. Turbine Housing

Check turbine housing (23) for erosion and pit marks. Inspect tapped holes for damaged threads. Inspect exhaust gas inlet flange for cracks. Inspect housing contour for wiping/scoring by turbine wheel blades due to excessive shaft radial play. Inspect gasket surfaces for nicks and other damage.

b. Compressor Housing

Check compressor housing (1) for erosion and pit marks. Check fence for cracks and security of mounting. Inspect tapped holes for damaged threads. Inspect scroll for wiping or scoring by impeller blades as a result of excessive shaft radial play.

c. Turbine Wheel And Shaft

Inspect turbine wheel (19) for nicked, bent, cracked, or missing blades. Inspect edges of blades to ensure they have not rubbed the turbine housing contour and changed profile as a result of excessive shaft radial play. Inspect sides of shaft seal groove for excessive wear.

Check for carbon buildup in bottom of groove. Check bearing journals for discoloration caused by overheating. Check for scoring due to dirt in oil. Replace turbine shaft if scratches/scoring cannot be removed by lightly rubbing with crocus cloth. Inspect bearing thrust surface (large diameter shoulder at turbine end of shaft), and replace shaft if thrust surface is scored or rough.

NOTE: The bearing-to-journal contact surface is only 5/16" wide at each end of the bearing journal.

d. Impeller

Check impeller (5) for nicked, bent, cracked, or missing blades. Inspect edges of blades to ensure they have not rubbed the compressor housing contour and changed profile. Excessive shaft radial/end play will cause this condition.

e. Bearing Housing

Inspect machined surfaces of bearing housing (14) for nicks and other damage. Check O-ring seat and snap-ring groove for damage. Check shaft seal bore in turbine end of housing. A grooved bore indicates that the seal was stuck in shaft groove and turned with shaft, in which case the bearing housing must be replaced. Make certain seal bore chamfer is free of carbon and nicks to ensure ease of shaft seal installation.

f. **Bearing**

Inspect bore and thrust surfaces at each end of the bearing (12). Replace bearing if there is any evidence of wear or roughness. Make certain the flange and OD of bearing are free of nicks.

g. Shaft Spacer

Inspect thrust surfaces of shaft spacer (11) and replace if there is any evidence of roughness. Inspect sides of grooves for excessive wear and check for carbon buildup in bottom of grooves.

h. Oil Retainer Plate

Inspect oil retainer plate (7) for nicks which could cause O-ring damage. Inspect shaft seal bore. If there is evidence of grooving caused by shaft seal sticking and turning with shaft, replace retainer plate. Make certain shaft seal bore chamfer is clean and free of nicks to ensure ease of shaft seal installation.

i. **Turbine Wheel Shield And Spring-Ring**

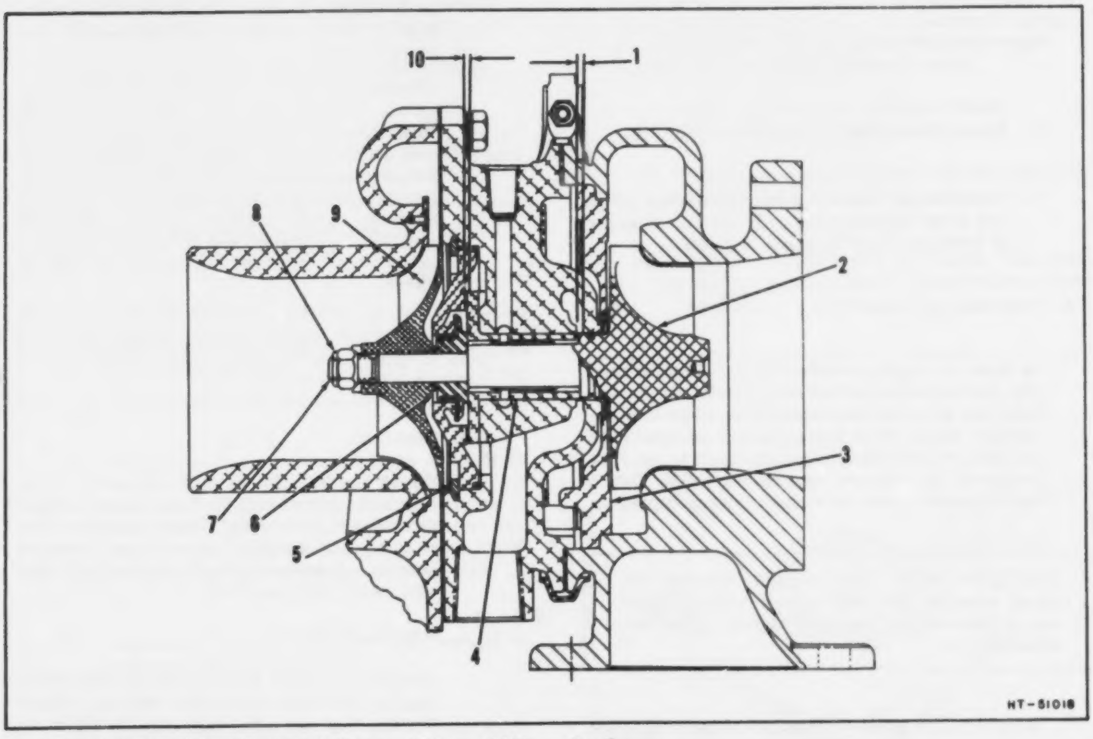
Inspect turbine wheel shield (17) for flatness, evidence of rubbing or scoring, and for eroded/pitted surfaces subjected to hot gases. Examine spring-ring (16) for damage, loss of tension, and warpage.

j. Clamp

Inspect turbine housing clamp (21) for cracks, stripped threads, distortion, and other damage.

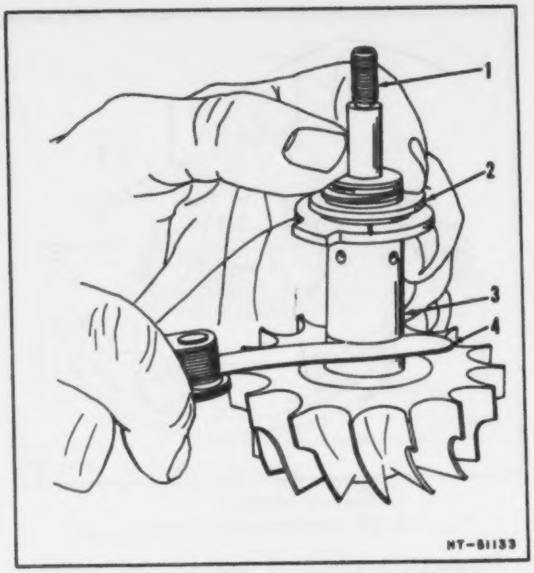
4. Reassembly

Before starting to reassemble the turbocharger, make sure all parts are thoroughly clean and free of grease, grit, metal chips, etc. Parts should be free of nicks and burrs and as such, must be handled with care to prevent subsequent damage/marring of machined surfaces. The work bench area and tools must be kept clean at all times.



1. Bearing to turbine shaft end play - .004" - .008"
2. Turbine wheel and shaft
3. Turbine wheel shield
4. Turbine shaft bearing
5. Snap ring
6. Shims
7. Total shaft end play - .005" - .009"
8. Maximum shaft radial play - .022"
9. Impeller to compressor housing - .015" - .020"
10. Bearing to retainer end play - .001 - .003"

Figure 12. Turbocharger Clearance Check Points

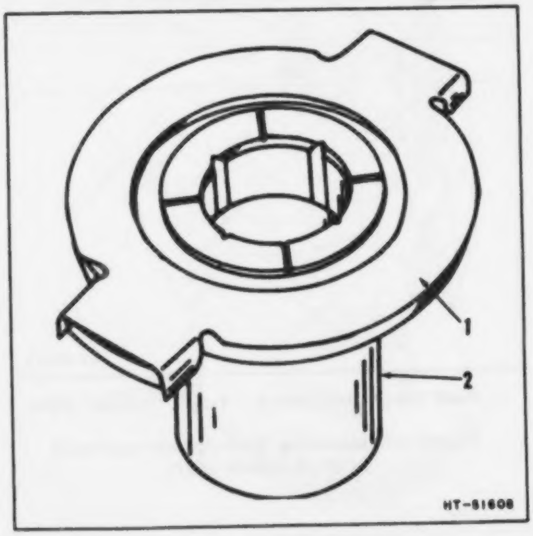


1. Turbine wheel and shaft
2. Shaft spacer
3. Turbine shaft bearing
4. Feeler gauge

Figure 13. Measuring Bearing to Turbine Shaft End Play

To assemble the turbocharger:

a. Install mounting fixture in the bearing housing oil drain line hole. Clamp mounting fixture in a bench vise so bearing housing is in a horizontal position, flat side up, Figure 8.



1. Shim
2. Bearing

Figure 14. Bearing-Shim Assembly

b. Install 2 pipe plugs previously removed for cleaning of housing (2). Tighten plugs to 140-200 lb. in. torque.

c. Determine bearing to shaft end play as follows:

(1) Place bearing, Figure 13 (3), and spacer (2) on shaft (1).

(2) Hold spacer (2) tight against shaft shoulder and measure clearance between bearing (3) and shaft (1) with a feeler gauge. Clearance should be .004" - .006". If end play clearance exceeds .006" replace bearing to attain specified clearance.

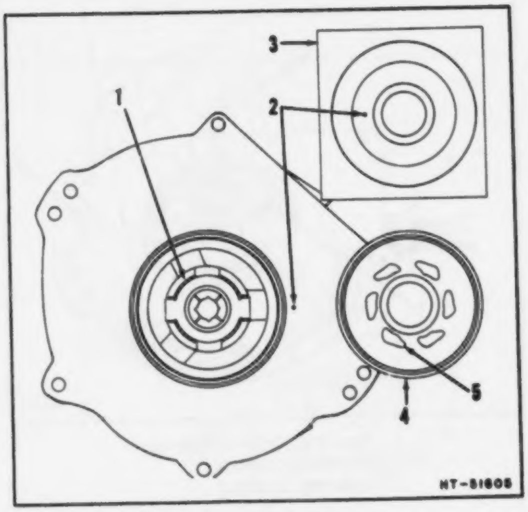
(3) Record bearing to shaft end play clearance for subsequent use in determining total shaft end play and impeller shim requirements.

d. Install bearing as follows:

(1) Make certain shim is attached securely to tangs of bearing, Figure 14.

NOTE: The service replacement bearing with shim replaces the plain bearing.

(2) Install bearing-shim assembly into bearing housing Figure 16, with bearing flange tangs engaging bearing housing lugs and in alignment with punch mark on bearing housing, Figure 15.



1. Bearing housing lugs
2. Punch marks
3. Top View - oil retainer plate
4. Bottom View - oil retainer plate
5. Oil retainer plate pads

Figure 15. Oil Retainer Plate and Bearing Housing Alignment Marks

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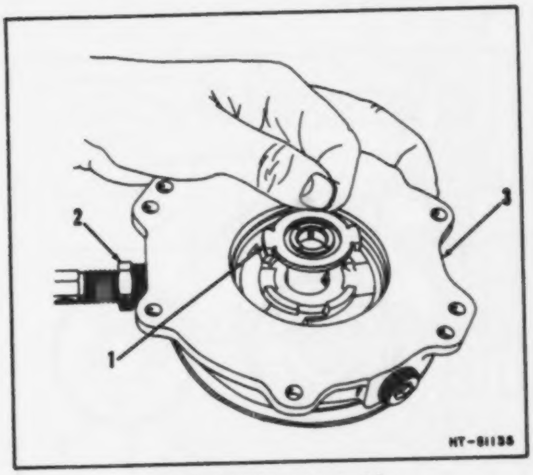
NOTE: If no punch mark exists, add punch mark to the bearing housing, Figure 15. When a position 90° from original position must be used because of wear on side of bearing housing lugs, identify new position with a double punch mark.

NOTE: The oil retainer plate should have a punch mark on its top side, Figure 15, which is centered with one of its pads. This will locate full pads on each of the bearing flange tangs.

e. Lubricate oil retainer plate O-ring and install it in the bearing housing, Figure 17.

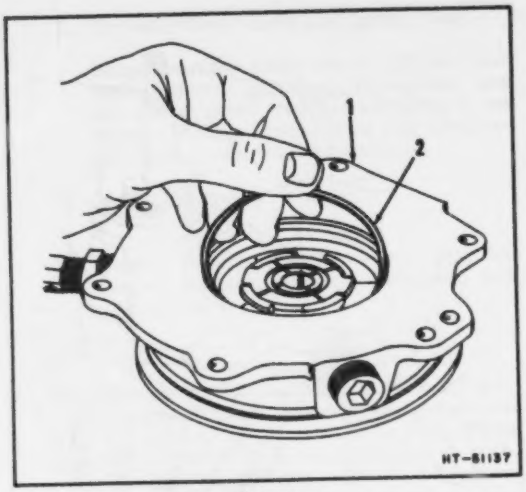
f. Lubricate grooves of shaft spacer with clean engine oil. Expand shaft seals just enough to slide them over shaft spacer and into grooves. Position the 2 shaft seals so their gaps are opposed.

g. Hold assembled shaft spacer at a slight angle in relation to the oil retainer plate as shown in Figure 18. Work side opposite gap of first seal into bore, then force gap side of seal into bore. Tilt shaft spacer in opposite direction to start side opposite gap of second seal into bore, then force gap side of seal into bore.



1. Bearing shim assembly
2. Mounting fixture
3. Bearing housing

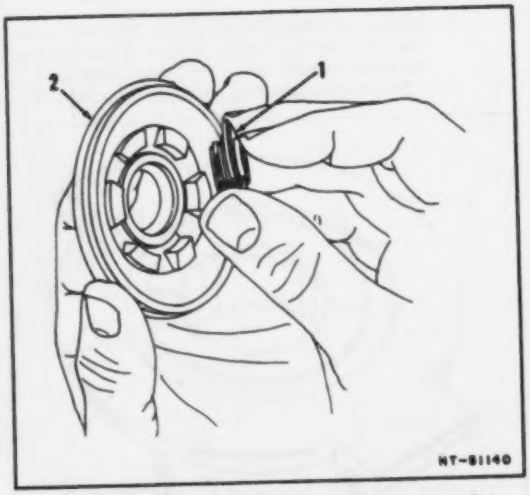
Figure 16. Installing Bearing in Bearing Housing



1. Bearing housing
2. Oil retainer plate O-ring

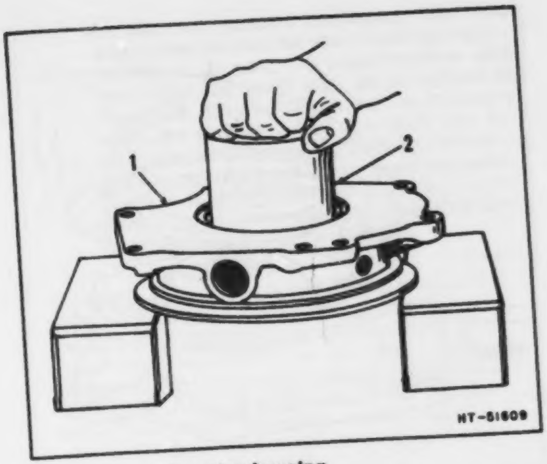
Figure 17. Installing Oil Retainer Plate O-Ring

h. Make certain O-ring is fully seated in bearing housing. Position assembled oil retainer plate, shaft spacer, and seals in bearing housing.



1. Shaft spacer with seals 2. Oil retainer plate

Figure 18. Installing Shaft Spacer and Seals in Oil Retainer Plate



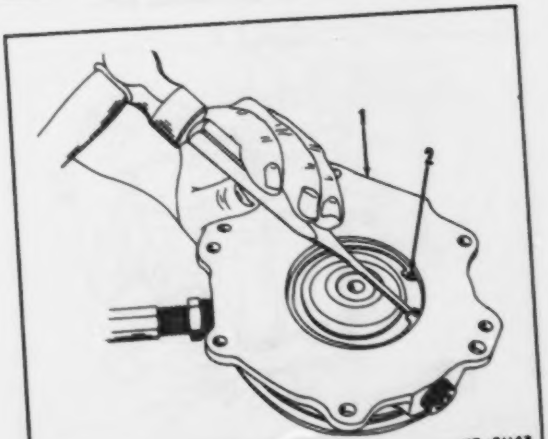
1. Bearing housing
2. Oil retainer plate installer

Figure 19. Pressing Oil Retainer Plate Into Bearing Housing

i. Align punch mark on oil retainer plate with punch mark on bearing housing, Figure 14. Place oil retainer plate installer (Paragraph H, Item 4) on retainer plate, Figure 19, and using hand force, press into place as far as it will go.

j. Install snap-ring to hold oil retainer plate in position. Tap ends of snap-ring, Figure 20, to make certain it is firmly seated.

CAUTION: Be sure to install snap-ring with tapered side up.



1. Bearing housing
2. Bearing retaining snap-ring

Figure 20. Installing Bearing Retaining Snap-Ring

k. Determine bearing to oil retainer plate end play and total shaft end play as follows:

(1) Position dial indicator so contact point rests on spacer, Figure 21 (1). Make sure spacer (1) is all the way in against bearing in housing (3). Set indicator on zero. Push up on bearing and note reading on dial indicator.

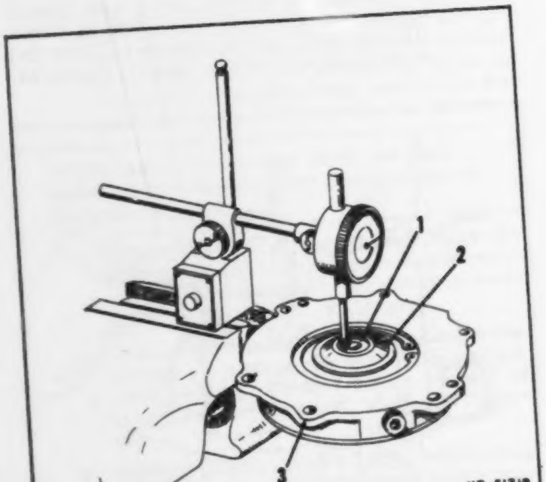
(2) End play clearance should be .001" - .003". If clearance exceeds .003" possibly the retainer plate or snap-ring is not seated properly.

(3) Bearing to retainer plate end play just determined plus the bearing to turbine shaft end play determined previously in Step 3 is the total shaft end play and should be .005" - .009". Record this total for subsequent use in determining impeller to compressor housing clearance and impeller shim requirements.

l. To determine impeller to compressor housing clearance and impeller shim requirements:

(1) Position impeller over oil retainer plate, Figure 7 (7), with impeller hub resting on spacer (11) and the spacer (11) resting on the bearing (12).

(2) Place gasket (2) and compressor housing (1) on bearing housing (14). Secure by installing 3 of the 6 capscrews (15) at equal intervals around the housings. Tighten capscrews to 80-100 lbs. in.



1. Turbine shaft spacer
2. Oil retainer plate
3. Bearing housing

Figure 21. Measuring Bearing to Oil Retainer Plate End Play

(3) Position dial indicator as shown in Figure 22 so contact point rests on the impeller end. Grasp impeller with suitable pliers and raise as far as it will go. Note dial indicator reading.

(4) Subtract total shaft end play determined in Step k, (3) from indicator reading just obtained and record the difference.

(5) Select a combination of .010" - .015" impeller shims that will total .015" - .020" less than the difference arrived at in Step l, (4).

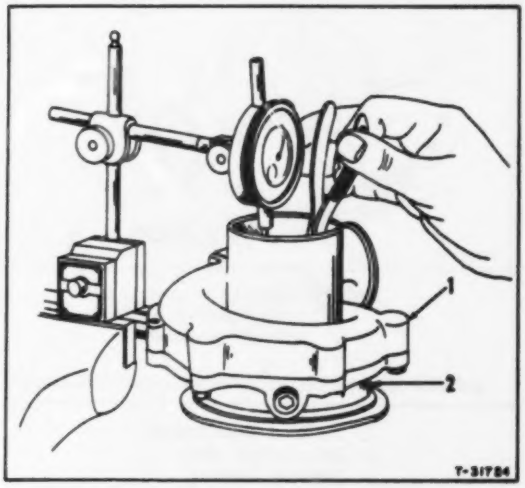
> NOTE: .015" - .020" is the minimum and maximum impeller to compressor housing clearance.

Following is a hypothetical example:

Given	.049"	dial indicator reading from Step l, (3)
minus	.006"	total shaft end play from Step k, (3)
Equals	.043"	difference.
Then	.043"	difference
minus	.025"	thickness of one 0.010" shim and one 0.015" shim
Equals	.018"	impeller to housing clearance.

m. Remove 3 capscrews, compressor housing, and impeller from the bearing housing.

n. Turn bearing housing over and install spring-ring Figure 7 (16). Position shield (17) with the 3 projections spaced over flat areas of spring-ring as shown in Figure 23.



1. Compressor housing 2. Bearing housing

Figure 22. Determining Impeller Shim Requirements

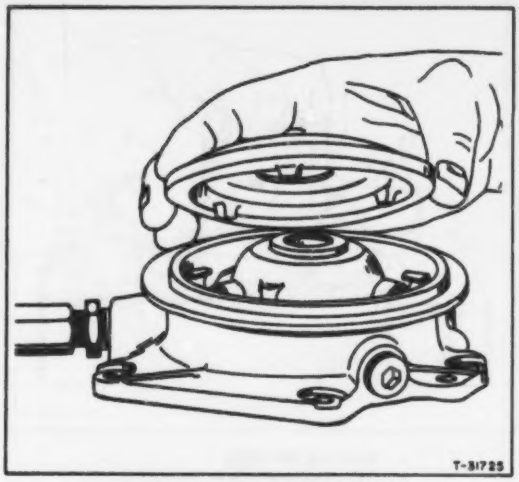
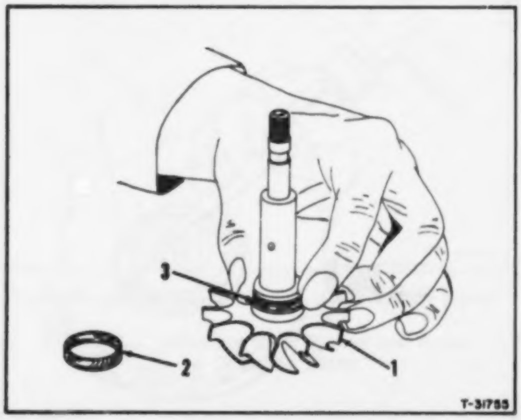


Figure 23. Positioning Turbine Shield on Bearing Housing

o. Install C-clamps to hold turbine wheel shield against tension of the spring-ring, Figure 25.

p. Lubricate turbine shaft groove with oil and install shaft seal.

q. Lubricate bearing journals of the turbine wheel and shaft. Insert shaft into bearing, Figure 25, using light pressure to force shaft seal into its bore in housing (2). If seal comes out of the shaft groove, start this operation over using a thin 6" scale to assist entrance of seal into housing bore.



1. Turbine wheel and shaft
2. Suppressor
3. Suppressor and seal

Figure 24. Positioning Suppressor on Shaft Seal

An alternate method employs a shaft seal suppressor to hold the shaft seal during installation. In use, the suppressor is slid down over the shaft seal as illustrated in Figure 24. The shaft seal is held compressed while the turbine wheel and shaft are installed in bearing housing bore and remains in the completed assembly. The suppressor is made of plastic-like material which completely disintegrates on contact with exhaust temperatures of 300° to 400°F.

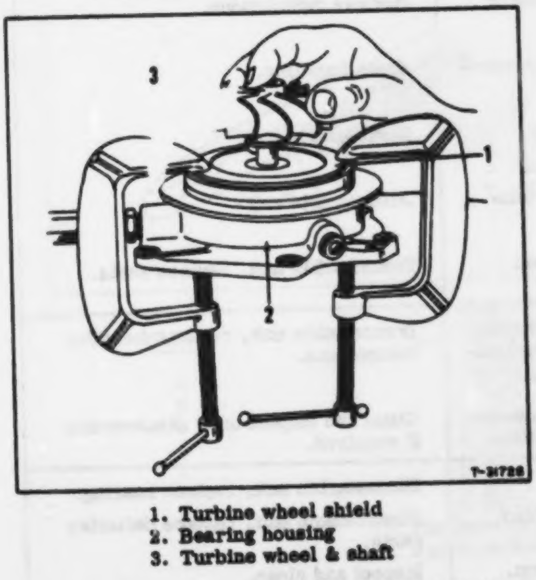
NOTE: A suppressor is included in a SHAFT SEAL AND SUPPRESSOR KIT which also contains 3 shaft seals used in turbocharger.

CAUTION: After installation of the turbine wheel and shaft assembly, rotate turbine wheel. If it does not turn freely shaft and seal are not properly installed.

r. Remove partially assembled turbocharger unit from bench vise and replace it, compressor side up. Place impeller shims and impeller over turbine shaft end. (Refer to preceeding Step l. for shim pack requirements.)

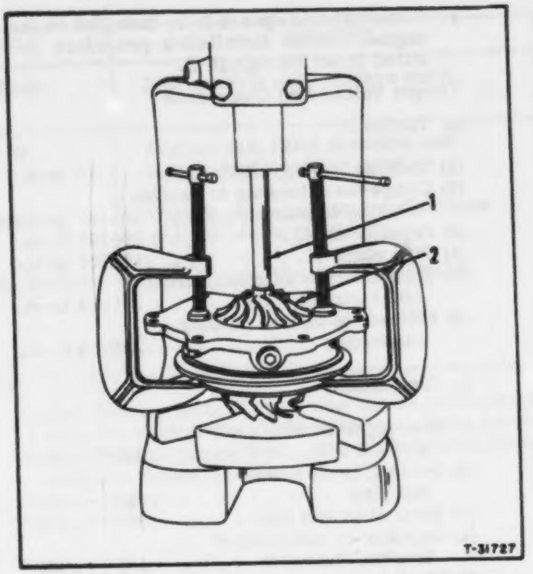
CAUTION: Do not allow turbine wheel and shaft to drop from bearing housing. Damage of these precision made parts will result.

s. Place assembly in a press with turbine wheel hub positioned firmly on press base plate, Figure 24. Press impeller into place on turbine shaft using installer tool, Figure 28 (5).



1. Turbine wheel shield
2. Bearing housing
3. Turbine wheel & shaft

Figure 25. Installing Turbine Wheel and Shaft



1. Impeller installer 2. Impeller

Figure 26. Pressing Impeller on Turbine Wheel Shaft

NOTE: As an alternate method of assembly, impeller may be heated in a dry oven to a temperature not to exceed 300°F. and installed onto turbine shaft without use of a press.

t. Place assembly in a bench vise, impeller side up. Position impeller washer and install self-locking nut on the left-hand threads of turbine shaft. Use a cloth as shown in Figure 27 to hold the turbine, and tighten the self-locking nut to 80-100 lbs. in. torque.

NOTE: Again check total shaft end play to make certain impeller has been pressed all the way onto shaft.

u. Attach gasket and compressor housing to the bearing housing using capscrews, lockwashers, and plain washers. Tighten capscrews evenly to 80-100 lbs. in. torque.

v. Using clean engine oil, lubricate assembly through oil inlet opening until oil flows from drain opening. Check for free rotation of assembled turbine wheel, shaft, and impeller.

w. Position gasket, Figure 7 (22), and housing (23) on housing (14) and secure with clamp (21). Install nut (20) on clamp screw and tighten to 5-10 lbs. in. torque.

x. When turbocharger is not going to be installed immediately, cover all openings to prevent damage and entrance of foreign matter.

y. When turbocharger is to be installed on the engine, follow installation procedure detailed under Paragraph E.

5. Torque Values And Clearances

a. Torques:

(1) Turbine housing clamp nut . . 5-10 lb-in.
(2) Compressor housing to bearing housing capscrews . . . . . 80-100 lb-in.
(3) Impeller nut . . . . 80-100 lb-in.
(4) Pipe plugs . . . . 140-200 lb-in.
(5) Turbocharger to exhaust manifold locknuts . . . . 18-21 lb-ft.
(6) Diffuser to turbine housing capscrews . . . . 28-33 lb-ft.

b. Clearances:

(1) Bearing to turbine shaft end play . . . . .004" - .006"
(2) Bearing to oil retainer plate end play . . . . .001" - .003"
(3) Total shaft end play . . . . . .005" - .009"
(4) Impeller to compressor housing clearance . . . . .015" - .020"
(5) Maximum shaft radial play (Impeller end) . . . . .022"

G. TROUBLESHOOTING

The troubleshooting list which follows is of use in diagnosing and correcting unsatisfactory turbocharger and engine operation. Each trouble symptom is followed by a list of probable causes and the recommended remedy. Although some of the symptoms are similar to those produced by a faulty turbocharger, they are actually the direct result of faulty engine operation. Correct faulty engine conditions before repairing the turbocharger.

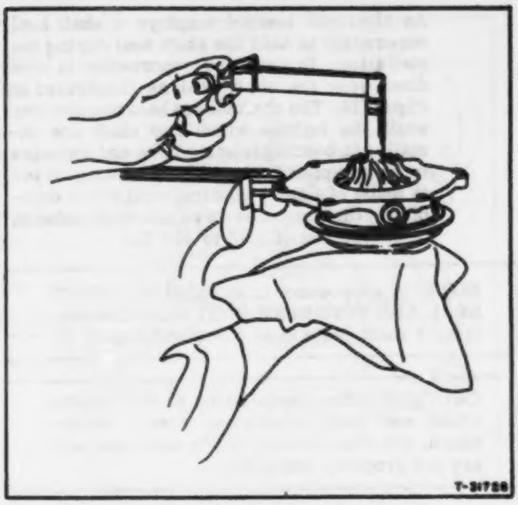


Figure 27. Tightening Impeller Nut

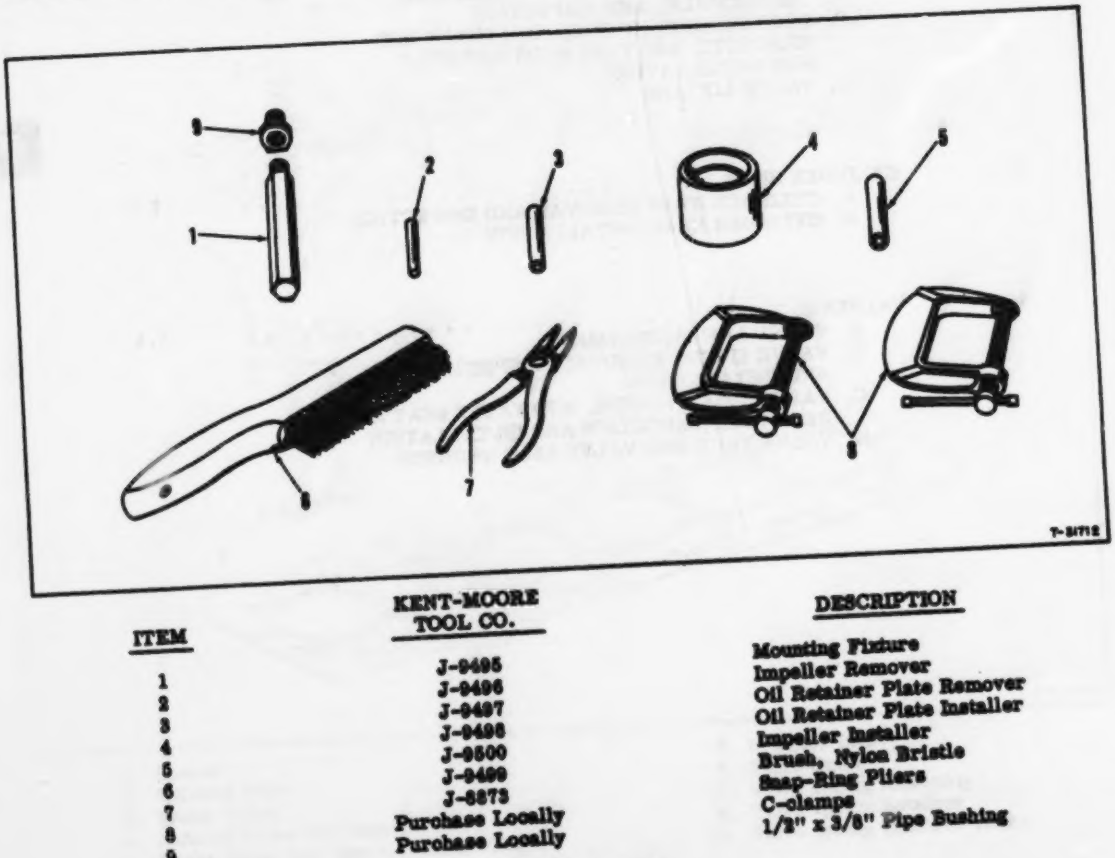
TROUBLE	POSSIBLE CAUSE	REMEDY
Smoking engine exhaust, loss of engine power.	Dirty air cleaner.	Clean air cleaner.
	Restricted intake manifold or piping.	Remove restrictions.
	Foreign matter or dirt accumulation on impeller.	Clean impeller.
	Interference or binding in rotating assembly.	Disassemble unit.
	Damaged impeller or turbine wheel.	Disassemble unit.
	Excessive oil leakage from seals.	Disassemble unit, replace seals.
Noisy rotating assembly.	Damaged bearing or other components causing rotating assembly to rub against housing.	Disassemble unit, replace defective components.
	Foreign matter or carbon accumulation obstructing rotation.	Clean and inspect unit, disassemble if required.
Excessive vibration.	Damaged bearing.	Disassemble unit, replace bearing.
	Damaged impeller or turbine blades.	Disassemble unit, replace defective parts.
	Restricted induction system.	Inspect and clean.

TROUBLE	POSSIBLE CAUSE	REMEDY
Excess oil in intake manifold or exhaust stack.	Excessive oil leakage from seals.	Disassemble unit, replace seals.
Low turbo speed; power loss; clean exhaust.	Insufficient fuel supply to engine.	Replace fuel filter elements and inspect fuel injection pump.
	Leaking intake or exhaust manifold connections.	Tighten all connections and replace gaskets where required.
	Back pressure on turbo exhaust too high.	Open restriction in exhaust stack.

H. TOOLS

The following service tool listing was prepared to assist service and maintenance personnel in selection of proper tools and tool combinations required to accomplish various service and maintenance operations described and illustrated in this Topic.

The service tools listed below can be purchased on order from Kent-Moore Organization, Inc., Service Tool Division Order Dept., 1501 South Jackson Street, Jackson, Michigan.



ITEM	KENT-MOORE TOOL CO.	DESCRIPTION
1	J-9495	Mounting Fixture
2	J-9496	Impeller Remover
3	J-9497	Oil Retainer Plate Remover
4	J-9498	Oil Retainer Plate Installer
5	J-9500	Impeller Installer
6	J-9499	Brush, Nylon Bristle
7	J-8873	Snap-Ring Pliers
8	Purchase Locally	C-clamps
9	Purchase Locally	1/2" x 3/8" Pipe Bushing

Figure 28. Tools

SECTION 7

VALVES, VALVE OPERATING MECHANISM, AND CYLINDER HEAD

TOPIC TITLE

1 GENERAL 7.1
    A. OPERATIONS WHICH DO NOT REQUIRE CYLINDER HEAD REMOVAL
    B. OPERATIONS WHICH DO REQUIRE CYLINDER HEAD REMOVAL

2 ROCKER ARMS, ROCKER ARM SHAFT AND BRACKETS, PUSH RODS, AND VALVE LIFTERS 7.2
    A. ROCKER ARMS, ROCKER ARM SHAFT AND BRACKETS, AND PUSH RODS REMOVAL, DISASSEMBLY, AND INSPECTION
    B. ROCKER ARMS, ROCKER ARM SHAFT AND BRACKETS, AND PUSH RODS ASSEMBLY AND INSTALLATION
    C. VALVE LIFTERS

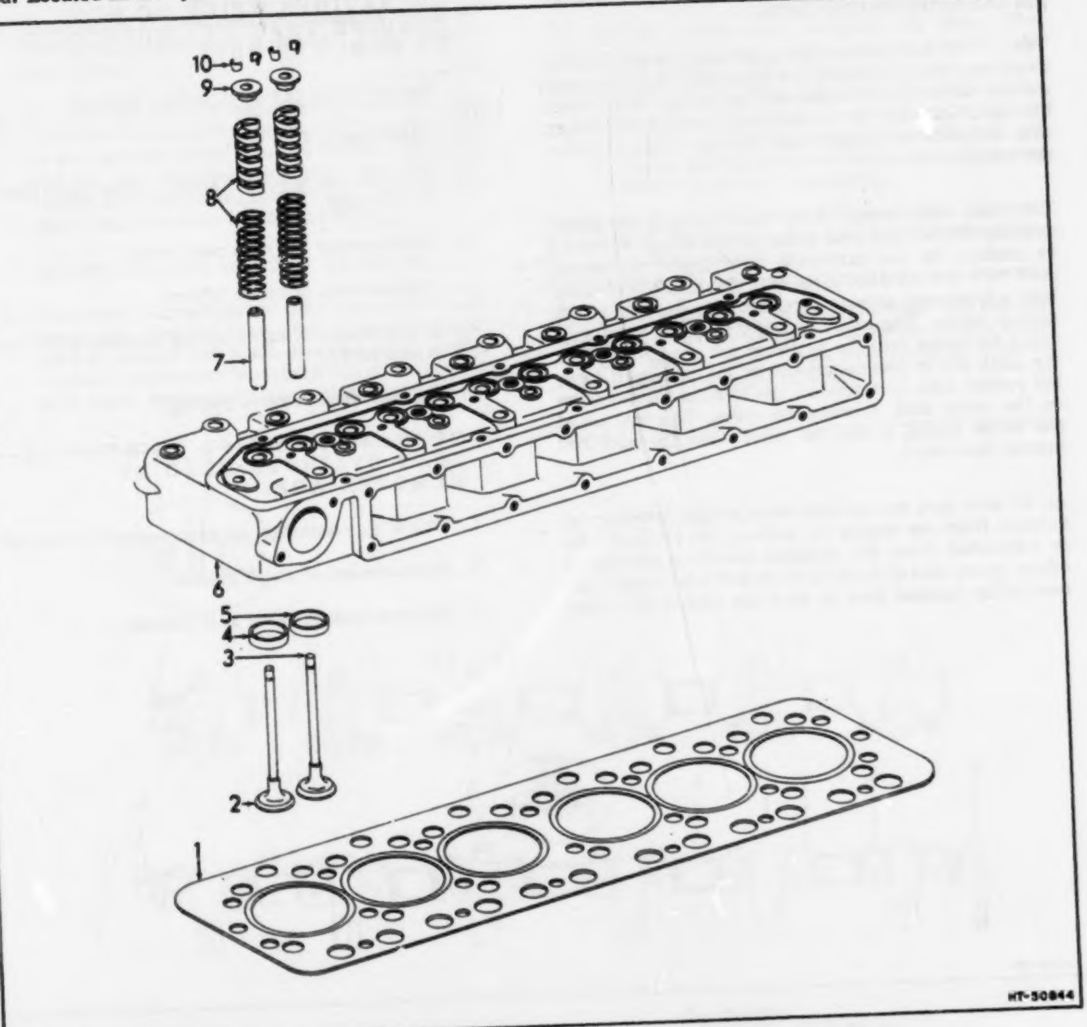
3 CYLINDER HEAD 7.3
    A. CYLINDER HEAD REMOVAL AND INSPECTION
    B. CYLINDER HEAD INSTALLATION

4 VALVES 7.4
    A. VALVE LASH ADJUSTMENT
    B. VALVE SPRING REMOVAL, INSPECTION AND INSTALLATION
    C. VALVE, VALVE GUIDE, AND VALVE SEAT INSERT REMOVAL, INSPECTION AND INSTALLATION
    D. VALVE FACE AND VALVE SEAT GRINDING

TOPIC 1. GENERAL

The cylinder head is a one-piece alloy iron casting and is secured to the upper part of the cylinder block by heat treated capscrews. Inlet and outlet ports are provided in the cylinder head for the intake of air and the expulsion of exhaust gases. Cored passages are provided for the circulation of the coolant. A gasket is installed to seal the compression and all water and oil passages between the cylinder block and cylinder head. Located in the cylinder head above each cylinder is an intake valve, valve guide, valve spring, spring retainer and locks, an exhaust valve, valve guide, valve spring, spring retainer and locks, a fuel injection nozzle, and two rocker arms. The top of the cylinder head is enclosed with a cylinder head cover and sealed with a gasket.

The intake and exhaust valves are made of special alloy steel. The valves are carefully heat-treated to



1. Gasket
2. Exhaust Valve
3. Intake Valve
4. Exhaust Valve Seat Insert
5. Intake Valve Seat Insert (Service Only)
6. Cylinder Head
7. Valve Guide
8. Valve Spring Assembly
9. Valve Spring Retainer
10. Valve Spring Retainer Locks

Figure 1. Cylinder Head Assembly Details

develop the special properties required for valve service. Each valve stem is hardened and accurately ground to size.

The hardened exhaust valve seat inserts, installed in the cylinder head, are accurately ground to very close limits and their freedom from warpage under ordinary working conditions reduces valve grinding to a minimum. The valve guides, made of special alloy iron, are pressed into the cylinder head and hold the valves in accurate alignment with the valve seats. Cylindrical valve springs with dampers are held in place on the upper end of the valve stems by spring retainers and spring retainer locks.

The rocker arm assembly, consisting of two rocker arms for each cylinder, is mounted on a common rocker arm shaft supported by rocker arm shaft brackets attached to the cylinder head. One rocker arm actuates the intake valve and the other actuates the exhaust valve.

The push rods extend down thru the cylinder head, cylinder block, and into valve lifters which are held in position by the camshaft. The upper end of the push rods are concave to receive the ends of the valve lash adjustment screws threaded into one end of the rocker arms. The other end of the rocker arm actuates the valve thru the action of the push rod. When the push rod is forced upward by the camshaft lobe, the rocker arm is raised on one end and forced down on the other end, opening the valve. The tension of the valve spring closes the valve when the push rod moves downward.

An oil hole thru the cylinder head at the flywheel end extends from the engine oil gallery. An oil feed tube is connected from the cylinder head to a restrictor elbow in one end of the hollow rocker arm shaft. Excess oil is dumped thru an oil drain tube at the other end of the rocker arm shaft. Oil is forced out of the shaft thru the oil hole at each rocker arm location and into the drilled passage of each rocker arm, providing lubrication for the rocker arm bushing. The oil spills down at the front end over the push rods and valve springs and drains back to the oil pan.

Service on some parts contained in the cylinder head can be accomplished with the head installed on the engine. For other service the head must first be removed from the engine.

A. OPERATIONS WHICH DO NOT REQUIRE THAT CYLINDER HEAD BE REMOVED ARE:

1. Replacement of fuel injection nozzles.
2. Adjustment of valves.
3. Replacement of rocker arms, rocker arm shaft, or brackets.
4. Replacement of valve push rods.
5. Replacement of valve lifters.
6. Replacement of valve spring retainers and retainer locks.
7. Replacement of valve springs.

B. OPERATIONS WHICH DO REQUIRE THAT CYLINDER HEAD BE REMOVED ARE:

1. Grinding, reseating, or replacement of valves.
2. Replacement of valve guides.
3. Replacement of valve seat inserts.

TOPIC 2. ROCKER ARMS, ROCKER ARM SHAFT AND BRACKETS, PUSH RODS, AND VALVE LIFTERS

A. ROCKER ARMS, ROCKER ARM SHAFT AND BRACKETS, AND PUSH RODS REMOVAL, DISASSEMBLY, AND INSPECTION

1. Remove cylinder head cover capscrews and washers and remove the cylinder head cover.

2. Disconnect oil feed tube compression nut from fitting in cylinder head at flywheel end of rocker arm shaft.

3. Remove the six 3/8" capscrews, washers, and lockwashers securing the rocker arm brackets to the cylinder head. Remove the six long capscrews and hardened washers securing the rocker arm brackets; remove the rocker arms, shaft, and brackets as an assembly.

4. Withdraw the push rods from the engine.

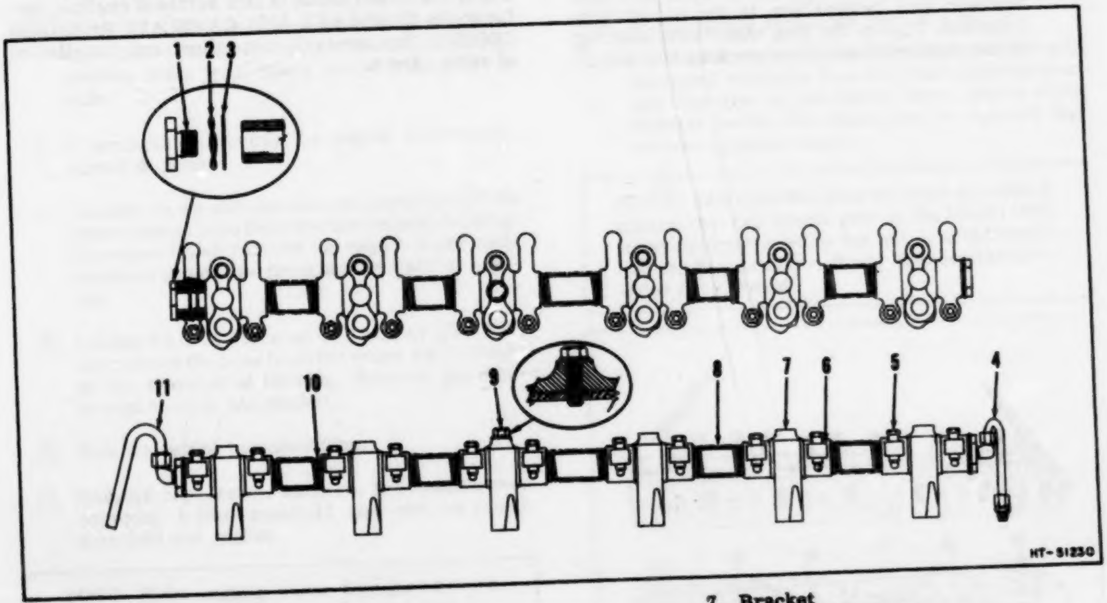
5. Disconnect compression nuts and remove oil drain tube and oil feed tube at corresponding ends of rocker arm shaft. Remove plug, spring washer, and washer from each end of the rocker arm shaft. Remove shaft locating capscrew and lockwasher in the top of the rocker arm bracket (third bracket from front end); slide rocker arms, springs, and brackets from the rocker arm shaft.

6. Inspect end of rocker arm adjusting screws and end of rocker arms. If they are worn, the rocker arm assemblies must be replaced.

7. Inspect rocker arm bushings for wear. The I.D. of the rocker arm bushing is 1.001" to 1.002" and the O.D. of the rocker arm shaft is .999" to 1.000". The specified clearance of the rocker arm shaft to the rocker arm bushing is .001" to .003" and must not exceed .005". If bushings are excessively worn, the rocker arm assemblies must be replaced.

NOTE: Bushings are non-replaceable in rocker arm assemblies.

8. Inspect rocker arm shaft for wear and replace if necessary. Clean oil holes in rocker arms and rocker arm shaft with solvent, a small wire, and compressed air.



1. Plug
2. Spring Washer
3. Washer
4. Oil Feed Tube
5. Adjusting Screw
6. Rocker Arm
7. Bracket
8. Rocker Arm Shaft
9. Locating Capscrew
10. Spring
11. Oil Drain Tube

Figure 1. Rocker Arms, Shaft and Brackets Assembly

9. Inspect both ends of push rods for signs of wear; polish out any nicks or scores. If push rods are bent, twisted, or damaged, they must be replaced.

B. ROCKER ARMS, ROCKER ARM SHAFT AND BRACKETS, AND PUSH RODS ASSEMBLY AND INSTALLATION

1. Align hole in rocker arm shaft with threaded hole in top of rocker arm bracket (third bracket from front of engine) and install shaft locating capscrew and lockwasher securely.
2. Lubricate rocker arm bushings and shaft with clean engine oil and install rocker arms, springs, and brackets on the rocker arm shaft. Install washer, spring washer, and plug at each end of shaft. Tighten plugs to a torque of 40 lbs. ft. at each end. Install oil drain tube at front end and oil feed tube at flywheel end of rocker arm shaft.
3. Install push rods in engine with cup end to the top. Make certain push rods are seated properly in the valve lifters.
4. Position rocker arms, shaft, and brackets assembly on cylinder head and align rocker arm adjusting screws in the push rod cup ends. Install the six long capscrews and hardened washers; also install the six 3/8" capscrews, washers and lockwashers in the rocker arm brackets. Tighten the long capscrews, starting at the center of the head and working alternately towards each end, to a torque of 130 to 140 lbs. ft. and tighten the 3/8" capscrews to a torque of 28 to 33 lbs. ft.

NOTE: Lubricate capscrew threads with a light coat of engine oil before installing. Also refer to Paragraph C, Topic 3 of this Section.

5. Connect the oil feed tube securely to the fitting in the top of the cylinder head at the flywheel end.
6. Adjust intake and exhaust valves to cold tappet clearance of 0.018". Run engine for approximately one hour, preferably under load, with minimum coolant temperature of 160°F. Retighten capscrews to the above torque values; then adjust the valve lash to 0.015" hot. Refer to VALVE ADJUSTMENT AND CYLINDER HEAD Topic, in Section 1.
7. Install cylinder head cover securely with capscrews and washers.

NOTE: Make certain cover gasket is in good condition. Replace as necessary.

C. VALVE LIFTERS

Due to the construction of this series of engines, refer to the CAMSHAFT AND CAMSHAFT BEARINGS SECTION for removal, inspection, and installation of valve lifters.

TOPIC 3. CYLINDER HEAD

A. CYLINDER HEAD REMOVAL AND INSPECTION

1. Drain the cooling system.

2. Depending upon the engine application, remove or disconnect all components and/or assemblies necessary for access to the cylinder head, such as exhaust pipe, engine hood, air cleaner, mounting brackets or braces, etc.

3. Remove wire from air heater element.

> NOTE: If engine is equipped with an ether starting aid instead of an air heater, remove the ether starting aid tube.

4. If engine is equipped with a turbocharger, disconnect the turbo oil lines and remove the turbocharger assembly. Remove elbow on top of intake manifold.

5. If engine is equipped with an air compressor loosen clamps on hoses and remove compressor air intake tube. Loosen clamps and remove hose from air compressor to thermostat housing.

6. If applicable, remove capscrews securing coolant filter bracket to intake manifold allowing coolant filter with hoses intact to hang to one side.

7. If applicable, remove the engine mounted instrument panel.

8. Loosen clamp and remove the upper end of the water bypass hose from the thermostat housing. Disconnect and remove the engine water temperature gauge tube from the thermostat housing.

9. Loosen the hose clamp on the radiator inlet hose and remove the hose from the water outlet flange on the thermostat housing. Remove the thermostat housing and gasket.

10. Remove engine breather tube.

11. Remove capscrews, washers, and lockwashers securing intake manifold and remove intake manifold and gasket.

> NOTE: Make certain water temperature gauge tube is carefully moved to one side before removing intake manifold.

12. Remove capscrews and washers securing exhaust manifold and remove exhaust manifold and gaskets or exhaust manifold sections as an assembly and gaskets, depending upon the application.

13. Disconnect the fuel drip manifold from the top of the fuel injection nozzles and from the fuel return fitting on top of the fuel injection pump; remove the fuel drip manifold. Disconnect and free the fuel lines from the fuel injection nozzle holders. Cover all fuel line openings to prevent the entrance of dirt or dust.

14. Remove the nuts and lockwashers securing the nozzle holder assemblies and carefully remove the nozzle holder assemblies.

> CAUTION: Use care when removing a fuel injection nozzle assembly to prevent striking the nozzle tip.

15. Remove cylinder head cover capscrews and washers and remove cylinder head cover.

16. Disconnect oil feed tube compression nut from fitting in cylinder head at flywheel end of rocker arm shaft.

17. Remove the six 3/8" capscrews and lockwashers securing the rocker arm brackets to the cylinder head. Remove the six long capscrews and hardened washers securing the rocker arm brackets; remove the rocker arms, shaft, and brackets as an assembly.

18. Withdraw the push rods from the engine.

19. Remove the remaining twenty capscrews and hardened washers securing the cylinder head and the two engine lifting eyes. Use a sling similar to the one illustrated in Figure 1 and remove cylinder head.

> NOTE: Lift cylinder head straight up until it clears the two dowel pins in the block; then move cylinder head to the left to avoid bending the fuel injection lines. Remove the cylinder head gasket.

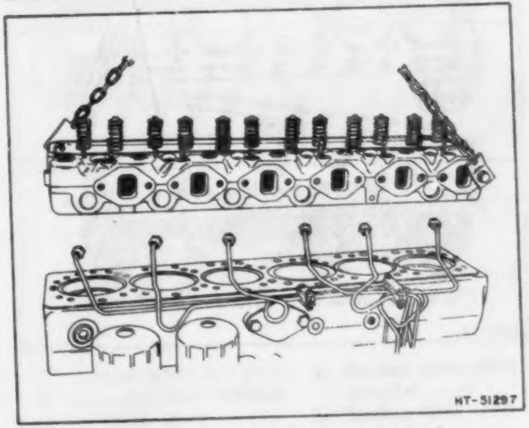


Figure 1. Removing Cylinder Head

20. Inspect the cylinder head and component parts for wear or damage. Repair or replace any worn or damaged parts. If cylinder head is to be replaced, thoroughly inspect the parts removed from the old head before installing them in the new head. The proper procedure to be followed in making the inspection and installation of the various parts can be found in pertinent Topics in this Section. Make certain that the cored water and air passages and drilled oil holes in the cylinder head are clean. Clean carbon from injection nozzle bore in cylinder head (refer to FUEL SYSTEM Topic, Section 1).

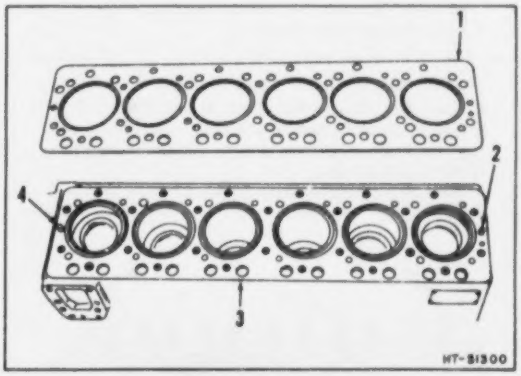
B. CYLINDER HEAD INSTALLATION

Make certain that the machined surfaces of the cylinder block and the cylinder head are thoroughly clean. A new cylinder head gasket must be used before installing the cylinder head.

> CAUTION: Before the cylinder head is installed, make certain that there is not an excessive amount of oil, or any other liquid, in the capscrew holes in the cylinder block. Too much oil in any of these holes may cause a hydrostatic lock and crack the cylinder block when the capscrew is tightened.

Install the cylinder head as follows:

1. Thoroughly clean top deck of cylinder block and under-side of cylinder head.



1. Cylinder Head Gasket
2. Dowel Pin
3. Cylinder Block
4. Dowel Pin

Figure 2. Installing Cylinder Head Gasket

2. Make certain that the cylinder sleeve standout is within the specified limits. The specified standout of each cylinder sleeve is .002" to .005" above the top flat surface of the cylinder block.

> NOTE: Correct specified standout, if necessary, by reconditioning sleeve seat in the block with recommended tool and installing sleeve shims under cylinder sleeve flange to obtain the 0.002" to 0.005" protrusion.

3. Install a new cylinder head gasket over the two dowel pins and onto the cylinder block with the indicated side down as stamped on the gasket. Do not use any sealer or gasket dope. The gasket as supplied has been pre-coated with a phenolic sealer and an anti-stick compound.

> NOTE: Fire rings are supplied with the cylinder head gasket in current models. Follow instructions packaged with the service cylinder head gasket.

4. Use a sling as illustrated in Figure 1 and position the cylinder head over the dowel pins and onto the cylinder block.
5. Lubricate threads of 20 short cylinder head capscrews with light coat of engine lubricating oil; install with hardened washers in cylinder head. Tighten capscrews to 90 to 110 lb-ft torque following sequence depicted in Fig. 3, Section A.

> CAUTION: Torque figures in this and following steps are based on engine oil lubricated threads. To prevent overstressing of capscrews, do not use extreme pressure lubricants of any kind.

6. Install push rods in engine with cup end to the top. Make certain push rods are seated properly in the valve lifters.
7. Position rocker arms, shaft, and brackets assembly on cylinder head and align rocker arm adjusting screws in the push rod cup ends. Install the six long capscrews and hardened washers; also install the six 3/8" capscrews and lockwashers in the rocker arm brackets. Tighten the long capscrews, starting at the center of the head and working alternately towards each end, to a torque of 90-100 lbs. ft. and the 3/8" capscrews to a torque of 28-33 lbs. ft.

> NOTE: Lubricate threads of capscrews with a light coat of engine oil before installing.

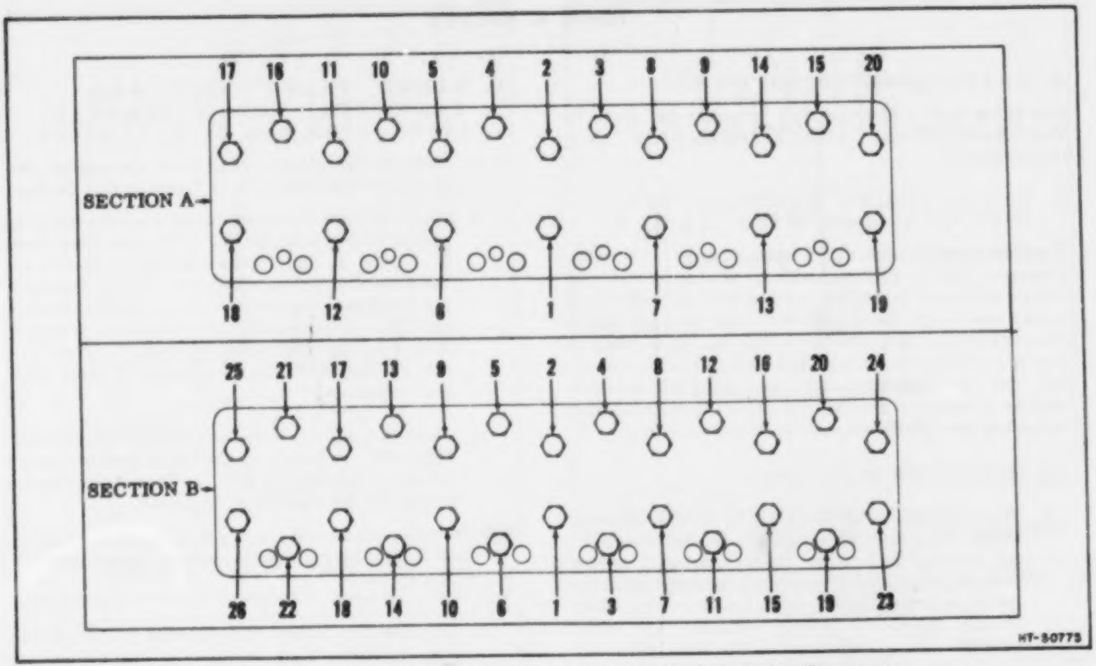


Figure 3. Cylinder Head Capscrew Locations and Torquing Sequence

8. Tighten the twenty six cylinder head capscrews in the numerical sequence specified in Figure 3, Section B, to 130-140 lbs. ft. torque.

> NOTE: The use of an offset cylinder head wrench or equivalent as illustrated in Figure 4 is required for tightening the capscrews under the rocker arm shaft assembly.

9. Retighten the twenty six capscrews in the numerical sequence specified in Figure 3, Section B, to 130-140 lbs. ft. torque.

10. Adjust all intake and exhaust valves to a cold tappet clearance setting of 0.018". Refer to VALVE ADJUSTMENT AND CYLINDER HEAD Topic, in Section 1.

11. Connect the oil feed tube to the fitting in the cylinder head and install cylinder head cover and gasket.

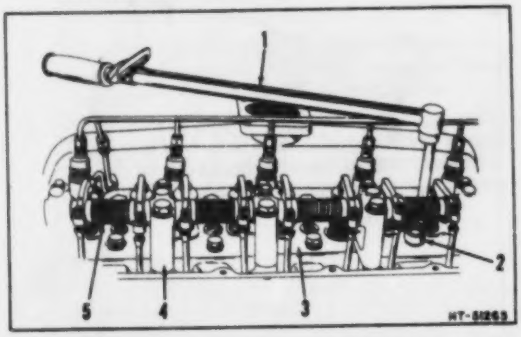
12. Complete the rest of the installation by a direct reversal of the removal procedure described in Paragraph A of this Topic in order to run the engine before making the final torquing of cylinder head capscrews and before making the final valve lash adjustment.

13. Fill the cooling system. Run engine for approximately one hour, preferably under load, with a minimum coolant temperature of 160°F.

14. Remove cylinder head cover and retighten all 26 capscrews to 130 to 140 lbs. ft. torque, following sequence depicted in Figure 3, Section B. If capscrew does not move when this specified torque is reached, back it off slightly by loosening, then retighten to specified torque. This is important in eliminating possible false torque readings due to temporary thread seizure.

15. Adjust valve lash to 0.015" hot. Refer to VALVE ADJUSTMENT AND CYLINDER HEAD Topic, in Section 1.

16. Inspect engine for fuel, water, or oil leaks and correct any leaks found.



1. Torque Wrench
2. Cylinder Head Wrench
3. Cylinder Head
4. Rocker Arm Shaft Bracket
5. Rocker Arm Shaft

Figure 4. Torquing Cylinder Head Capscrews

TOPIC 4. VALVES

A. VALVE LASH ADJUSTMENT

For valve lash adjustment procedures, refer to VALVE ADJUSTMENT AND CYLINDER HEAD Topic, in Section 1.

B. VALVE SPRING REMOVAL, INSPECTION, AND INSTALLATION

The intake and exhaust valve springs and valve spring retainers may be removed without removing the cylinder head from the engine, or when the cylinder head is removed from the engine the valve springs can be removed with a tool similar to the one illustrated in Figure 1. All valve springs are equipped with a damper. The valve spring and damper assembly is serviced as a unit. To remove the valve springs without removing the cylinder head, proceed as follows:

1. Remove cylinder head cover.
2. Make certain that the piston, in the cylinder from which the valve springs are to be removed, is at top dead center. Using a suitable spring compressing tool, remove spring retainer locks, and carefully release tension on the valve spring. Remove spring retainer and valve spring.
3. Inspect the valve springs for cracks. Both the intake and exhaust valve springs with dampers should have a specified load of 40-46 lbs. when compressed to a length of 2.237" (valve closed) and a load of 105-115 lbs. when compressed to a length of 1.780" (valve open). Install a new spring when old spring is 5% under or over the specified load limits.
4. Install the valve springs, valve spring retainers, and valve spring retainer locks using a direct reversal of the removal procedure.

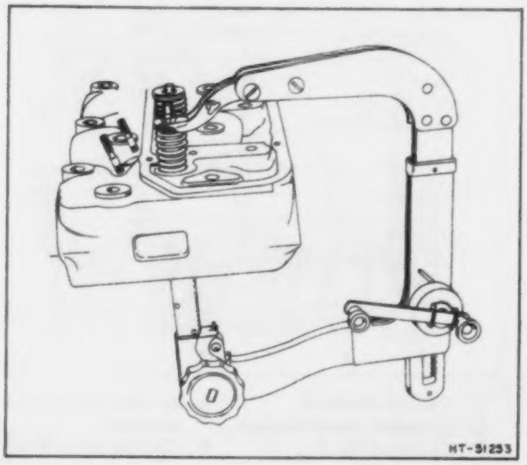


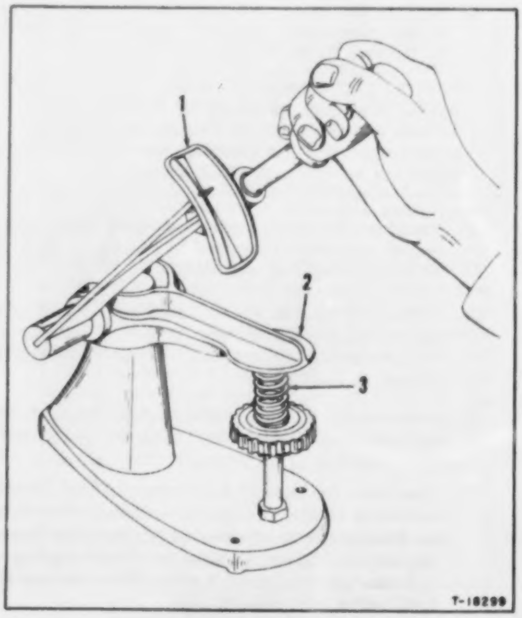
Figure 1. Removing Valve Spring Retainer Locks

C. VALVE, VALVE GUIDE, AND VALVE SEAT INSERT REMOVAL, INSPECTION AND INSTALLATION

1. Remove the cylinder head from the engine. Refer to CYLINDER HEAD Topic in this Section.
2. Place cylinder head on blocks; depress the valve spring with a tool similar to the one illustrated in Figure 1, and remove the valve spring retainer locks. Release the valve spring depressing tool and remove the valve spring retainer and the valve spring. Place valves in a rack as they are removed from cylinder head so they can be identified and reinstalled in their original locations.
3. Clean the carbon from the valve and valve seats. Clean the carbon from the valve guides using a valve guide cleaning tool (nylon brush) similar to the one illustrated in Figure 3.

CAUTION: Do not use a metal cutting type cleaning tool.

4. Replace the intake and exhaust valves if they are cracked, bent, burned or the stems are worn. The specified O.D. of the exhaust valve stem is .3705" - .371". The specified I.D. of



1. Torque Wrench
2. Valve Spring Testing Tool
3. Valve Spring

Figure 2. Testing Valve Spring

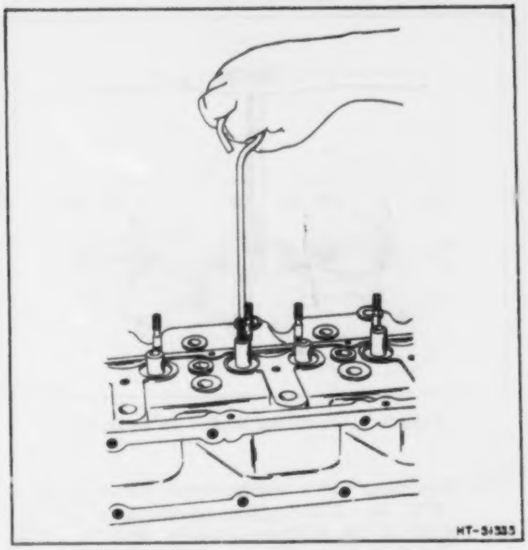
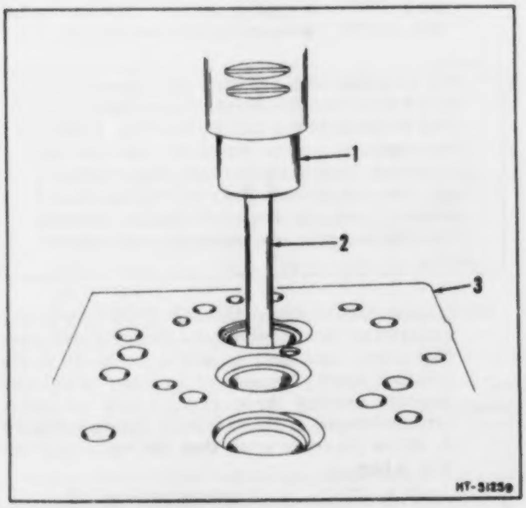
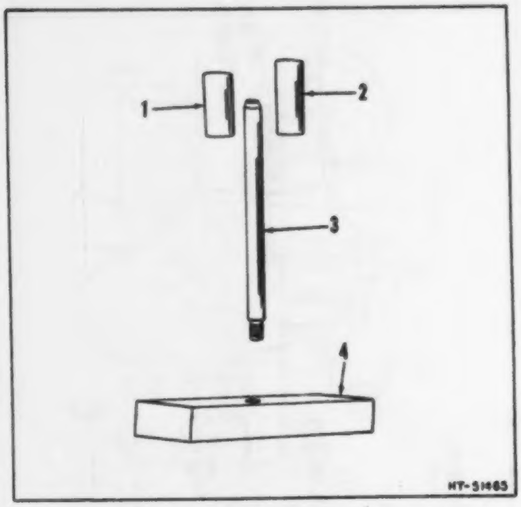


Figure 3. Cleaning Valve Guides



1. Press Ram
2. Valve Guide Removing Tool
3. Cylinder Head

Figure 4. Removing Valve Guide



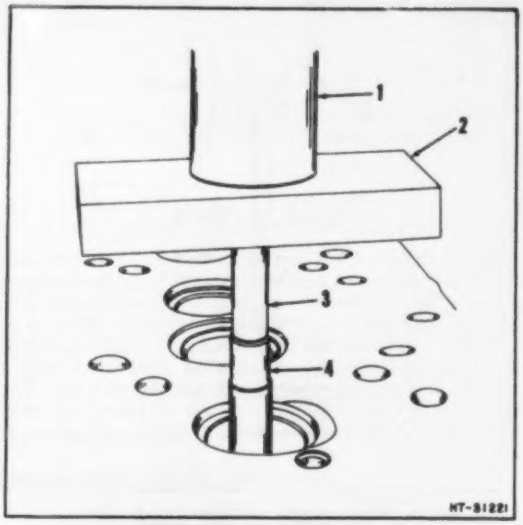
1. Intake Valve Guide Adapter
2. Exhaust Valve Guide Adapter
3. Pilot
4. Stop Plate

Figure 5. Tools for Installing Valve Guides

the exhaust valve guide is .373" (ream in field) giving a stem-to-guide clearance of .002" to .0025". Replace exhaust valve and/or guide if clearance exceeds .0055". The specified O.D. of the intake valve stem is .3715" to .372". The specified I.D. of the intake valve guide is .373" (ream in field) giving a stem-to-guide clearance of .001" to .0015". Replace intake valve and/or guide if clearance exceeds .0035".

NOTE: Valve guides in new production and new factory service heads do not require reaming in the field. They are factory bearingized to .3735" to .374" I.D.

5. The valve guides may be removed by pressing them out thru the top of the cylinder head, using a tool similar to the one illustrated in Figure 4.
6. The intake and exhaust valve guides are identical and must be installed with the 30° chamfer protruding thru the top of the cylinder head.
7. Press valve guides (Figure 6) into position (large tapered end down) from bottom of cylinder head with a guide installing tool, consisting of a stop plate (Figure 5), pilot, exhaust



1. Press Ram
2. Stop Plate
3. Intake Valve Guide Adapter
4. Intake Valve Guide

Figure 6. Installing Intake Valve Guide

valve guide adapter, and an intake valve guide adapter. The adapters establish proper protrusion of guides above the cylinder head. Use the 1-11/16" long adapter on the guide installing tool so that the exhaust valve guide protrudes 1-3/32" from the bottom of the counterbore on the top of the cylinder head, and use the 1-3/8" long adapter so that the intake valve guide protrudes 25/32" from the bottom of the counterbore on the top of the cylinder head. To use the tool, place cylinder head in a press with head gasket surface up. Assemble guide installing tool by screwing pilot into stop plate. Install adapter, exhaust or intake on the pilot. Install valve guide on the pilot with bottom end (end not tapered) against the adapter. Insert installing tool and guide into guide bore in cylinder head and press downward until stop plate rests on gasket surface of cylinder head.

> NOTE: To eliminate the possibility of scuffing guide or bore in the cylinder head, coat outside surface of guide with a mixture of white lead and lubricating oil before pressing guide into position.

8. After pressing valve guides into position, check the distance from the top of the guide to the counterbore in the cylinder head.

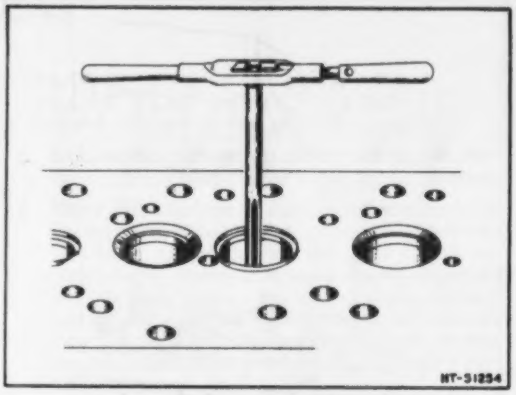


Figure 7. Reaming Intake Valve Guide

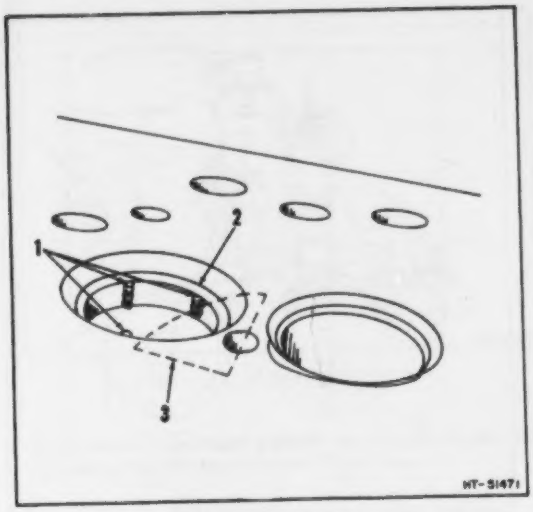
9. The bore of a replacement valve guide is .373" to .3735". The interference fit of a guide in the cylinder head is .0005" to .002". The guide bore will close approximately .001" when installed with the maximum interference fit. To resize valve guides after installation, use a .372" valve guide reamer first and follow with a .373" valve guide reamer (Figure 7).

> NOTE: Intake and exhaust valve guides installed in production and service replacement cylinder heads at the factory are sized with a "bearingized" tool. However, service replacement valve guides are not "bearingized"; they must be reamed after installation in the cylinder head. Do not ream guides already installed in service replacement cylinder head.

10. Inspect the valve seat inserts. If they are loose, cracked or pitted, new ones must be installed. The valve seat inserts are a press fit in the cylinder head. Remove valve seat inserts by electric welding three small beads on inside circumference of the insert as shown in Figure 8. Allow insert to cool, then lift out or pry out with a bar.

> CAUTION: Do not weld in encircled area (Figure 8). Protect machined surfaces from arc splatter.

If it becomes necessary to replace valve seat inserts, it is imperative that the original press fit be maintained between new inserts and insert bores in the cylinder head. If insert bores in cylinder head are damaged or worn enough so that the recommended press fit cannot be obtained when installing new standard size valve seat inserts, the bores must be



1. Weld Beads
2. Valve Seat Insert
3. Do Not Weld in This Area

Figure 8. Beads Welded on Exhaust Valve Seat Insert

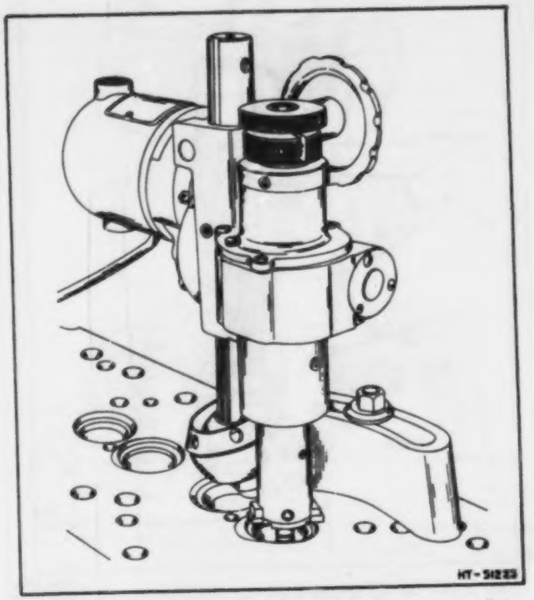


Figure 9. Reboring Cylinder Head to Accommodate Oversize Valve Seat Insert

machined .005" larger than their original I.D. using a tool similar to the one shown in Figure 9, and .005" oversize valve seat inserts must be installed.

> NOTE: New production cylinder heads do not have intake valve inserts; however, if the intake valve seats in the cylinder head are worn or pitted, intake valve seat inserts are available for service only. The cylinder head must be machined with a tool similar to the one illustrated in Figure 9 and intake valve seat inserts must be installed.

Refer to the following table for O.D. of valve seat inserts, corresponding I.D. of bores in cylinder head, and depth of counterbore.

The dimensions shown in the table provide an interference fit of .001" to .003" for both the exhaust and intake valve seat inserts. The depth of the counterbore in the cylinder head for the intake valve seat insert is .4585" to .4605" from the bottom deck of the cylinder head. The depth of the counterbore in the cylinder head for the exhaust valve seat insert is .4735" to .4755" from the bottom deck of the cylinder head.

11. Carefully install new valve seat inserts. Inserts must be started in place "true" with the counterbore in the cylinder head.

Install valve seat inserts as follows:

a. Make certain valve seat counterbores in cylinder head are clean, free of burrs, and

Valve Seat Insert	O.D. of New Insert	Insert Bore in Cylinder Head	Depth
Standard Size Exhaust	1.667" - 1.668"	1.665" - 1.666"	.4735" - .4755"
.005" Oversize Exhaust	1.672" - 1.673"	1.670" - 1.671"	.4735" - .4755"
Service Only Intake	1.816" - 1.817"	1.814" - 1.815"	.4585" - .460"

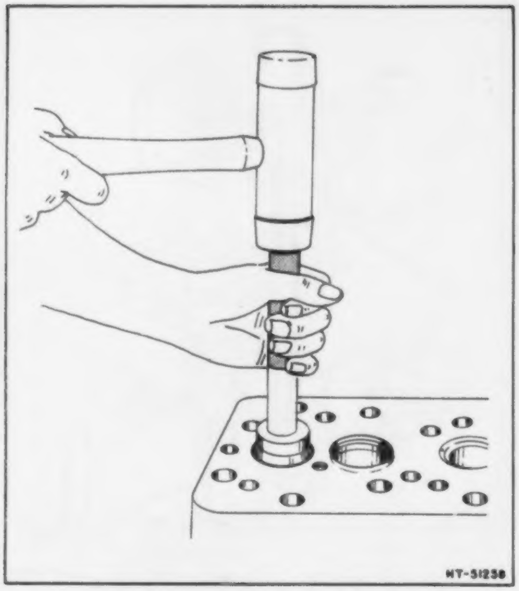


Figure 10. Installing Exhaust Valve Seat Insert

of the correct size to assure the specified interference fit (refer to table).

b. Chill inserts for two to four minutes in a dry ice container or cold box.

c. Place cylinder head bottom side up on a bench. Thoroughly clean counterbores for the inserts with compressed air and start an insert into the counterbore (valve seat side up).

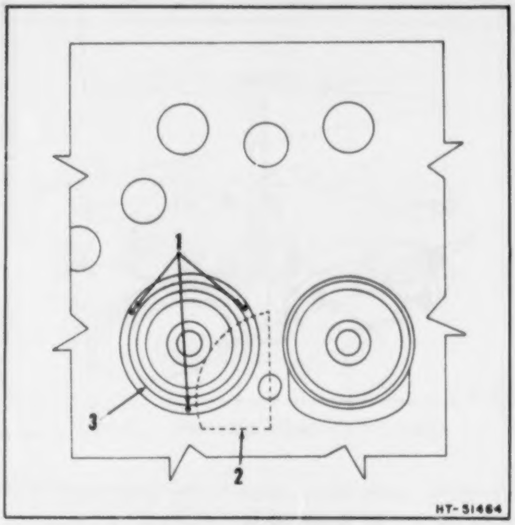
d. Use a valve seat insert installing tool similar to the one illustrated in Figure 10 and drive insert down tightly into counterbore. This operation must be done quickly while insert is cold.

e. It will be necessary to refinish valve seat inserts with a grinder. Refer to VALVE FACE AND VALVE SEAT GRINDING in this Topic.

12. After the inserts have been installed, the exhaust valve seat inserts must be staked to eliminate the possibility of the insert loosening in its bore. It is not necessary to stake the service intake valve seat inserts. Using a center punch and hammer, stake each exhaust valve seat insert at 3 points in the cylinder head approximately 1/32" from the O.D. of the insert and 120° apart and exactly as illustrated in Figure 11, being careful not to stake in the nozzle hole area. Do not use old staking points.

D. VALVE FACE AND VALVE SEAT GRINDING

Before installing either new valves or valves used previously, valve seats in cylinder head should be inspected for proper valve seating. If previously used valves are to be reinstalled, valve stems should be cleaned and valve faces ground to their specified angles of 45° for exhaust valve and 30° for intake valve. When refacing valves, remove all evidence of pitting and grooving. The valve guide should be cleaned with a nylon brush as shown in Figure 3. If bore in valve guide is worn oblong, or if valve head is warped relative to valve stem, the necessary parts must be replaced.



1. Staking Points
2. Do not stake in this area
3. Exhaust Valve Seat Insert

Figure 11. Exhaust Valve Seat Insert Staking Points

When new valve seat inserts are installed, or previously used inserts reseated, refinishing must be

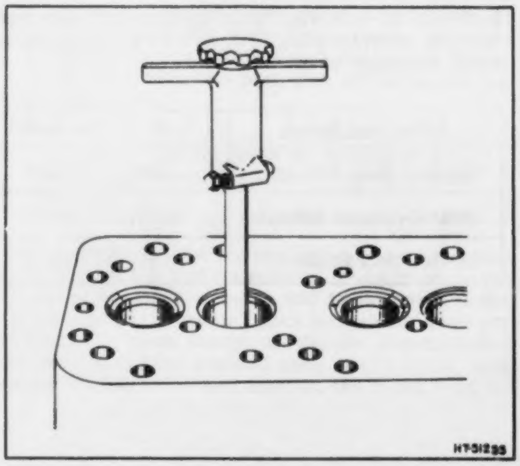


Figure 12. Installing Grinding Tool Pilot

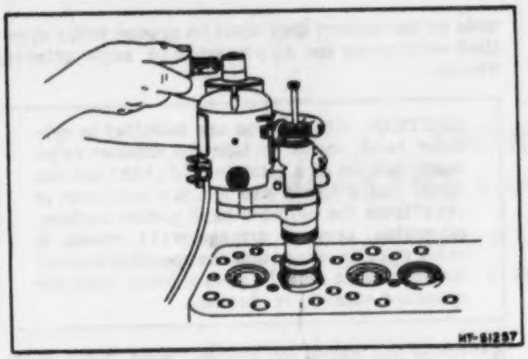
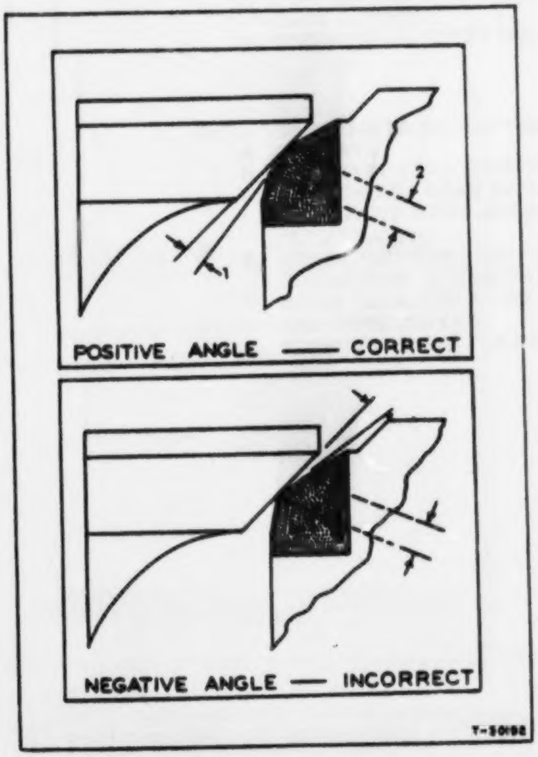


Figure 13. Grinding Valve Seat

done with a valve seat grinder set similar to the one shown in Figure 13.

NOTE: It is important that the valve grinder set be used according to the manufacturer's directions.



1. 1/2° to 1-1/2°
2. {3/32" Exhaust and Service Intake Insert Seat
   3/32" Intake Seat in Cylinder Head

Figure 14. Interference Angle

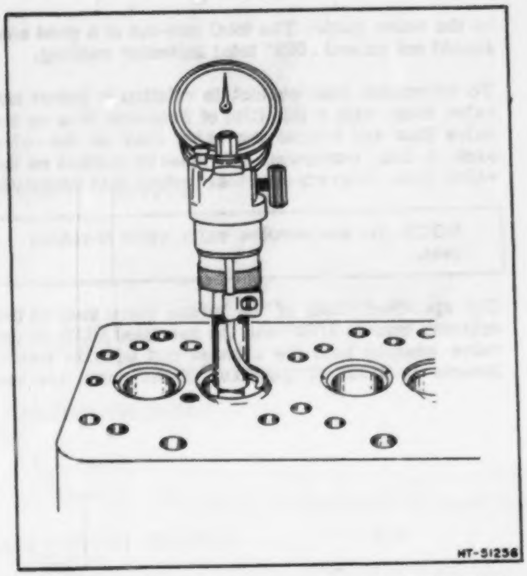


Figure 15. Checking Concentricity of Valve Seat

The usual equipment used with the valve seat grinder set includes the following items:

1. Valve seat grinder.
2. Dial gauge.
3. Tool pilot.
4. Four grinding wheels: 15°, 30°, 45°, and 60°.

The cutting face of the stone must be maintained at the correct angle and in proper condition by frequent dressing with a diamond wheel dresser. The frequency of dressing will be determined by condition of the seats and amount of metal required to be removed during the grinding operation.

By grinding valve face and insert seat at slightly different angles, a fine line contact of the face and seat is obtained, thus eliminating the need to lap the seating surfaces with grinding compound.

The difference of angles is termed "interference angle" and is usually 1/2° to 1-1/2°. The angle of the insert seat is made greater than that of the valve face, so as to assure contact at the top of insert seat. Thus, for the 45° exhaust valve face angle and a 1° interference angle, the insert seat grinder wheel must be dressed to grind the insert seat at an angle of 46°. Likewise, the insert seat for the intake valve must be ground at 31°. This is a positive interference angle. A negative angle, as illustrated in Figure 14, must be avoided. The first step in reconditioning the insert is to grind the seat, removing only enough metal to produce a pit-free continuous seat. After seat has been ground, use a dial gauge as shown in Figure 15 to check concentricity of the seat relative to the valve guide. The total run-out of a good seat should not exceed .002" total indicator reading.

To determine seat contact in relation to insert and valve face, wipe a thin film of Prussian Blue on the valve face and bounce the valve once on the valve seat. A thin, continuous line must be evident on the valve face, otherwise further grinding is required.

> NOTE: Do not revolve valve while checking seat.

The specified width of the intake valve seat on the cylinder head is 3/32" and the specified width of the valve seat on both the exhaust and service intake inserts is 3/32" (Figure 14). If the seats are too wide or too narrow they must be ground to the specified width using the appropriate angle grinding wheels.

> CAUTION: After valves are installed in cylinder head, make certain the exhaust valve heads are set in a minimum of .053" and the intake valve heads are set in a minimum of .054" from the cylinder head gasket surface, otherwise, serious damage will result. If valve stand-in is less than the specified amount the valve seat must be ground lower until the specified stand-in is obtained.

Assemble and install the cylinder head. Refer to the CYLINDER HEAD Topic in this Section.

SECTION 8
FRONT END AND GEAR TRAIN

TOPIC	TITLE	
1	CRANKSHAFT PULLEY AND DAMPER ASSEMBLY AND ENGINE FRONT SUPPORT	8.1
	A. GENERAL	
	B. CRANKSHAFT PULLEY AND DAMPER ASSEMBLY REMOVAL AND INSTALLATION	
	C. ENGINE FRONT SUPPORT	
2	TIMING GEAR COVER AND CRANKSHAFT FRONT OIL SEAL . . .	8.2
	A. GENERAL	
	B. TIMING GEAR COVER REMOVAL	
	C. CRANKSHAFT FRONT OIL SEAL REMOVAL AND INSTALLATION	
	D. TIMING GEAR COVER INSTALLATION	
3	GEAR TRAIN AND FRONT SUPPORT PLATE	8.3
	A. GENERAL	
	B. CAMSHAFT GEAR REMOVAL AND INSTALLATION	
	C. CRANKSHAFT GEAR REMOVAL AND INSTALLATION	
	D. FUEL PUMP DRIVE GEAR REMOVAL, AND INSTALLATION	
	E. HYDRAULIC PUMP DRIVE GEAR REMOVAL, INSPECTION, AND INSTALLATION	
	F. IDLER GEAR AND IDLER GEAR SHAFT REMOVAL AND INSTALLATION	
	G. FRONT SUPPORT PLATE	

TOPIC 1. CRANKSHAFT PULLEY AND DAMPER ASSEMBLY AND ENGINE FRONT SUPPORT

A. GENERAL

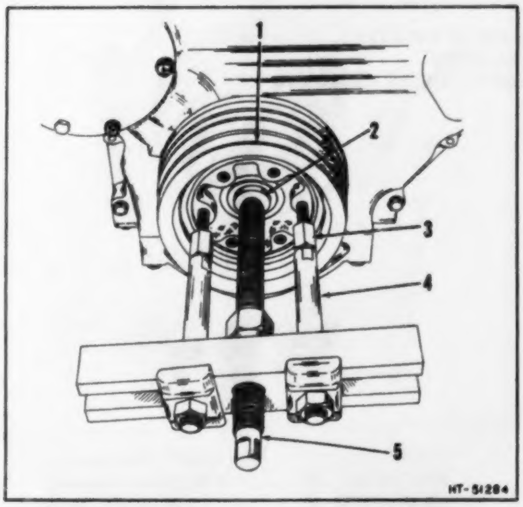
The type of crankshaft pulley and damper assembly used on this series of engines has a neoprene compound vibration damper bonded between the hub section and the pulley section of the assembly. Whenever the crankshaft pulley assembly must be replaced, it must be replaced as a unit for the parts are not serviced separately. The timing marks are rolled on the crankshaft pulley assembly for front end timing of the engine.

CAUTION: Do not, under any circumstances, fasten any type of additional pulleys or drive anything with the front crankshaft pulley and damper assembly that is not installed at the factory. Crankshaft breakage can occur if this precaution is not adhered to.

B. CRANKSHAFT PULLEY AND DAMPER ASSEMBLY REMOVAL AND INSTALLATION

1. Crankshaft Pulley Removal

a. If engine is installed in a unit, drain the cooling system. Remove components necessary to facilitate removal of the radiator, and remove the radiator.



1. Crankshaft Pulley and Damper Assembly
2. Shaft Protector
3. Leg Adaptor
4. Puller Leg
5. Forcing Screw

Figure 1. Removing Crankshaft Pulley and Damper Assembly

b. Release the tension on the water pump and alternator drive belts and remove the belts.

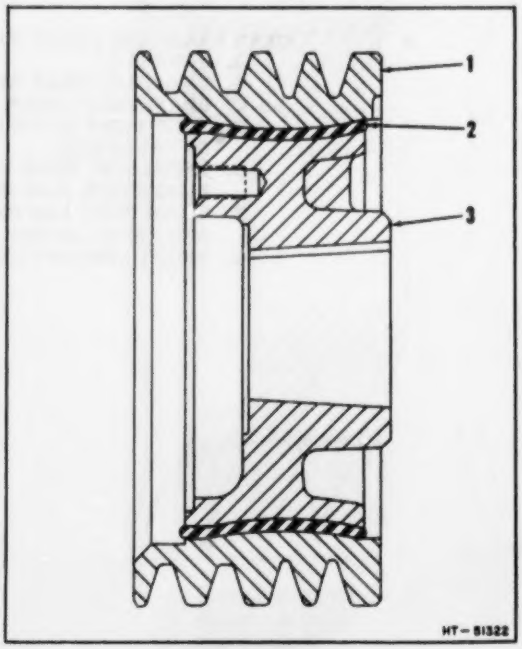
c. Loosen crankshaft pulley retaining capscrew and turn it out approximately 1/2".

d. Install leg adaptors into two opposite tapped holes of pulley and install a puller as illustrated in Figure 1.

CAUTION: Do not, under any circumstances, pry or pull on the pulley section (inertia member) of the crankshaft pulley and damper assembly (Figure 2).

e. Tighten puller forcing screw. To assist in loosening pulley hub from crankshaft, strike puller forcing screw with a soft headed hammer.

f. Remove puller tools, crankshaft pulley retaining capscrew, washer, crankshaft pulley assembly, and woodruff key.



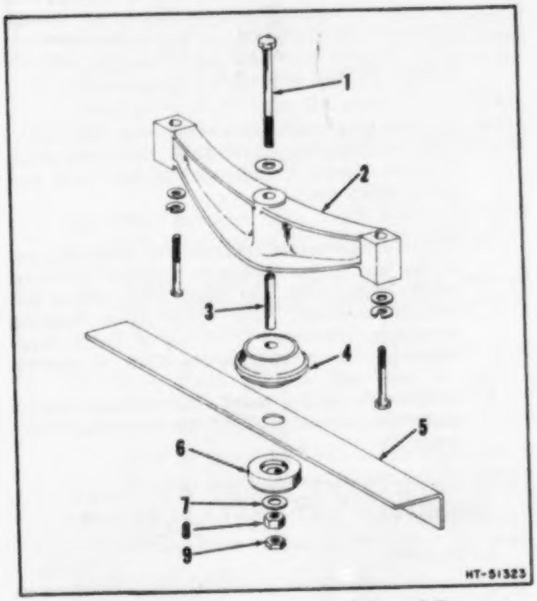
1. Inertia Member
2. Elastic Member
3. Hub Section

Figure 2. Crankshaft Pulley and Damper Assembly

2. Installation

a. Remove any burrs if necessary and install woodruff key into crankshaft keyway.

b. Position crankshaft pulley on woodruff key and install with washer and pulley retaining capscrew. Tighten capscrew to a torque of 200 to 220 lbs. ft.



1. Center Capscrew
2. Front Support
3. Sleeve
4. Compression Damper
5. Mounting Angle
6. Rebound Damper
7. Washer
8. Nut
9. Jam Nut

Figure 3. Engine Front Support with Front Mounting Angle

C. ENGINE FRONT SUPPORT

The engine front support is designed for single point suspension for the front end. It is of the vibration isolator type with a compression damper and a rebound damper. The unit must be installed with the proper tension on the center capscrew to give the proper holding characteristics. If either or both of the dampers become worn or deteriorated, they must be replaced.

1. Front Support Removal and Inspection

a. Remove jam nut, securing nut, washer, and rebound damper from center capscrew.

b. Jack up and support engine properly so that the front support can be removed.

c. Remove mounting capscrews, lockwashers, and washers securing front support to engine timing gear cover.

d. Remove engine front support.

e. Inspect parts for wear or deterioration and replace as ncessary.

2. Front Support Installation

a. Position engine front support, with center capscrew and washer included, under engine timing gear cover. Install mounting capscrews, lockwashers and washers. Tighten capscrews to a torque of 44 to 49 lbs. ft.

b. Install sleeve and compression damper; lower engine onto front mounting angle. Install rebound damper, washer and nut. Tighten nut to a torque of 45 to 50 lbs. ft. Secure nut in place with jam nut.

TOPIC 2. TIMING GEAR COVER AND CRANKSHAFT FRONT OIL SEAL

A. GENERAL

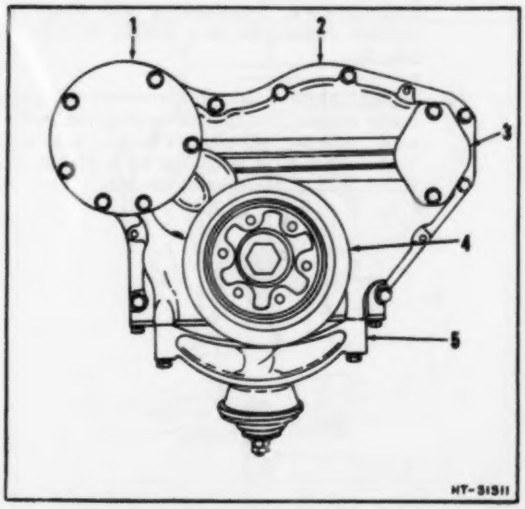
The timing gear cover encloses the gear train and the front end of the engine. The fuel pump drive gear inspection plate and the hydraulic pump cover plate are installed over the openings provided for them in the timing gear cover.

The unitized crankshaft front oil seal is located in the timing gear cover. The construction of the unitized seal is completely different from the lip-type seal and is made up of an inner part which fits tight on the crankshaft, and the outer part which is tight in the front cover. Sealing is accomplished by an internal contact (spring loaded) of the inner and outer parts of the seal and the two parts are so constructed that they form a single assembly.

> NOTE: Install a new oil seal each time the engine is disassembled.

B. TIMING GEAR COVER REMOVAL

1. Drain the cooling system and remove the components necessary to facilitate removal of the radiator, and remove the radiator.
2. Release the tension on the water pump and alternator drive belts and remove the belts.
3. If engine is equipped with an air compressor, remove air compressor drive belt.



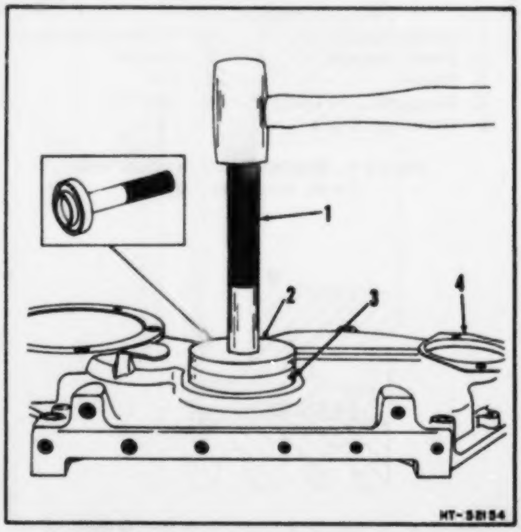
1. Fuel Pump Drive Gear Inspection Plate
2. Timing Gear Cover
3. Hydraulic Pump Cover Plate
4. Crankshaft Pulley and Damper Assembly
5. Engine Front Support

Figure 1. Timing Gear Cover and Inspection Plates

4. Remove crankshaft pulley and damper assembly and front engine support (refer to Topic 1 of this Section).
5. Remove capscrews and lockwashers securing the oil pan to the timing gear cover. To facilitate removal and installation of the cover, it is possible to loosen the oil pan capscrews enough to lower the front end of the oil pan; however, it is recommended that the oil pan be removed and all gaskets replaced.
6. Remove inspection plate capscrews, lockwashers, and fuel pump drive gear inspection plate. Remove thrust button with spring from fuel pump drive shaft.
7. Remove capscrews on front and back side securing timing gear cover to cylinder block and engine front plate. Jar cover loose with a soft headed hammer, pry cover from locating dowels, and remove it from engine, being careful not to damage front portion of oil pan gasket.
8. Before reinstalling cover, install a new crankshaft front oil seal (refer to the following Paragraph C).

C. CRANKSHAFT FRONT OIL SEAL REMOVAL AND INSTALLATION

1. Removal



1. Handle
2. Crankshaft Front Oil Seal Installer Tool
3. Crankshaft Front Oil Seal
4. Timing Gear Cover

Figure 2. Installing Crankshaft Front Oil Seal

a. Remove timing gear cover as described in preceeding Paragraph B.

b. Drive seal out from back side of cover.

c. Clean the bore in the cover to receive a new seal.

2. Installation

The O.D. of the front oil seal has a layer of red-colored sealant which forms a seal between the O.D. of the seal and the bore in the cover eliminating the need of using a sealing compound prior to pressing the seal into the cover. The I.D. of the seal has a layer of rubber compound to prevent oil leakage between the seal and the crankshaft.

a. Place cover on a flat surface with the front side to the top as illustrated in Figure 2.

b. Position seal in cover with open side of seal facing down and positioned squarely in bore of cover.

CAUTION: Make certain that seal is not cocked in cover bore.

c. Drive or press seal into cover bore until it bottoms. Using the tool illustrated in Figure 2 or one similar will properly position the seal in the cover bore, and will place the driving force on the outer edge of the seal.

CAUTION: Do not press on open face of seal or seal damage will occur.

d. After seal is installed in the cover, insert fingers into inner part of seal and check for rotation. If seal was installed properly, the inner part will turn with a firm feel to the fingers.

D. TIMING GEAR COVER INSTALLATION

1. Inspect and remove burrs from keyway in crankshaft, using a fine-cut mill file or stone, to prevent damaging the inner layer of rubber of the crankshaft oil seal.

2. Coat crankshaft lightly with engine lubricating oil.

3. Cement a new gasket to the timing gear cover.

4. Using a direct reversal of the removal procedure, position the gear cover on the two dowel pins in the cylinder block and complete the installation of the cover and the component parts. Tighten all capscrews securing the cover to a torque of 28-33 lbs. ft. Also tighten the six capscrews securing oil pan to timing gear cover to a torque of 28-33 lbs. ft.

5. Fill the cooling system.

TOPIC 3. GEAR TRAIN AND FRONT SUPPORT PLATE

A. GENERAL

Located under the timing gear cover at the front end of the engine is a completely enclosed train of helical gears as illustrated in Figure 1. The crankshaft gear, which is pressed and keyed onto the crankshaft, drives the camshaft gear which in turn drives the hydraulic pump drive gear (applies only on units equipped with a hydraulic pump). Also, the crankshaft gear drives the idler gear which in turn drives the fuel pump drive gear. The gear train is splash lubricated by oil thrown by the gears.

The gear train will run quietly if the gears and bearings are in good condition. The specified backlash between mating gears is given in FITS AND TOLERANCES, Section 1. As the gears or the bearings wear, the backlash will increase and the gear train may become noisy. New parts should be installed when the backlash between any two mating gears exceeds .015".

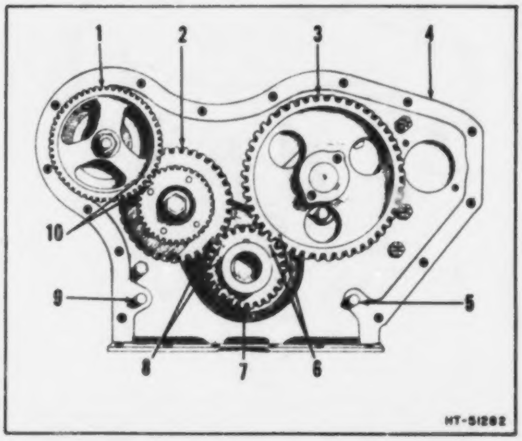
The gear train may be exposed by removing the timing gear housing cover as described in Topic 2 of this Section.

B. CAMSHAFT GEAR REMOVAL AND INSTALLATION

Refer to Section 11, CAMSHAFT, CAMSHAFT GEAR, AND CAMSHAFT BEARINGS.

C. CRANKSHAFT GEAR REMOVAL AND INSTALLATION

Refer to Section 13, CRANKSHAFT AND CRANKSHAFT GEAR, MAIN BEARINGS, AND MAIN BEARING CAPS.



1. Fuel Pump Drive Gear
2. Idler Gear
3. Camshaft Gear
4. Front Support Plate
5. Dowel Pin
6. Timing Marks
7. Crankshaft Gear
8. Timing Marks
9. Dowel Pin
10. Timing Marks

Figure 1. Gear Train

D. FUEL PUMP DRIVE GEAR REMOVAL AND INSTALLATION

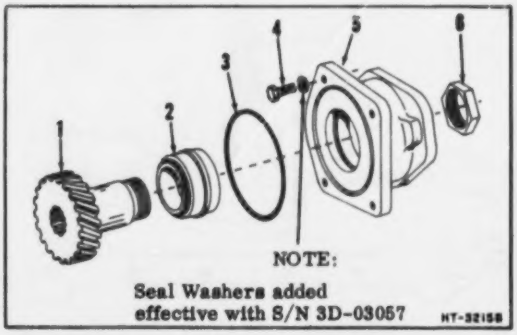
Refer to Section 4, FUEL SYSTEM.

E. HYDRAULIC PUMP DRIVE GEAR REMOVAL, INSPECTION, AND INSTALLATION

1. Remove hydraulic pump assembly from pump drive housing.
2. Remove cover plate at front of timing gear cover.
3. Straighten out crimped shoulder of shaft retaining nut and remove shaft retaining nut.
4. Force shaft and gear forward and remove from hydraulic pump housing through opening in timing gear cover. Front bearing cone will remain on shaft when shaft is removed.

> CAUTION: When removing shaft and gear from hydraulic pump housing, be careful that the bearing cone spacer does not fall down inside of the timing gear cover.

5. Inspect hydraulic pump drive gear and replace if gear is worn, scored, chipped, or has broken teeth.
6. The installation is a direct reversal of the removal procedure. Tighten shaft retaining nut to a torque of 240 to 260 lbs. ft. After torquing, crimp shoulder of retaining nut with a punch into slot in shaft.



NOTE:
Seal Washers added
effective with S/N 3D-03057

1. Hydraulic Pump Drive Gear
2. Bearing Set (includes bearing races, race spacer, bearing cones, and cone spacer)
3. O-ring
4. Lock Bolt and Seal Washer
5. Hydraulic Pump Drive Housing
6. Shaft Retainer Nut

Figure 2. Hydraulic Pump Drive Details

NOTE: The hydraulic pump drive housing is attached to the engine with two capscrews and two lock bolts. The two lock bolts and seal washers are found within the timing gear cover. When the timing gear cover is removed, the lock bolts can be removed without any difficulty. However, it is possible to remove the two lock bolts through the opening in the timing gear cover by special shaping (bending and grinding) of a 9/16" box wrench.

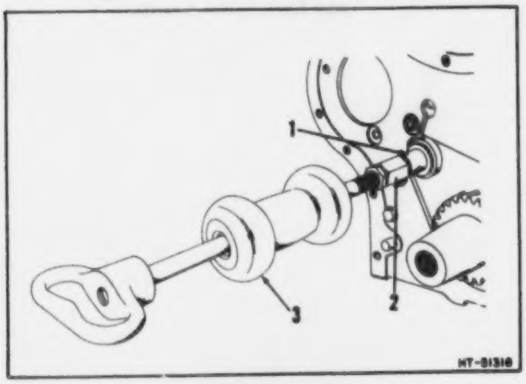
F. IDLER GEAR AND IDLER GEAR SHAFT REMOVAL AND INSTALLATION

The idler gear assembly contains two Timken roller bearings with a spacer between them. The bearings are lubricated with engine oil from the block which travels between the slot of the front plate and enters the drilled passage on top of the idler shaft. The idler shaft is pressed into the .998 - .999" bore in the cylinder block and the idler gear and the shaft are secured with a washer and capscrew that is secured into the cylinder block.

1. Idler Gear Removal
   - a. Remove timing gear cover as described in preceding Topic 2 of this Section.
   - b. Remove capscrew and washer securing idler gear.
   - c. Remove idler gear with bearings.
2. Idler Gear Shaft Removal

   If idler gear shaft is scored or worn it must be replaced. The specified O.D. on both ends of the idler gear shaft is .999" - 1.000".

   - a. Install a 9/16" - 18 adaptor in the end of the idler gear shaft. Install the end of the slide hammer into the adaptor and remove the idler gear shaft from the cylinder block.



1. Idler Gear Shaft
2. Adaptor
3. Slide Hammer

Figure 3. Removing Idler Gear Shaft

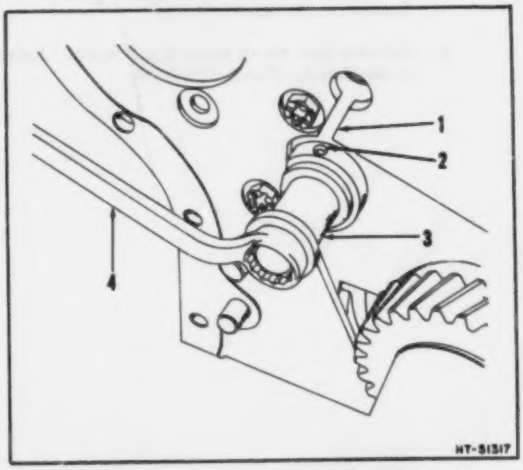
3. Idler Gear Shaft Installation
   - a. Position idler gear shaft into bore of cylinder block so that the oil hole in the top of the shaft lines up with the slot in the front plate.
   - b. Insert the washer and shaft securing capscrew into the shaft and tighten capscrew until the idler gear shaft bottoms in the cylinder block.
   - c. Remove washer and capscrew.
4. Idler Gear Installation

   The specified I.D. of the roller bearing is 1.000" - 1.0008" and the O.D. of the outer race of the bearing is 1.980" - 1.981". The specified I.D. of the idler gear is 1.9785" - 1.9795" and the I.D. of the groove in the idler gear for the spacer is 2.068" - 2.078". If the bearing assembly is worn, drive the outer races out with a punch and press in the new races until they contact the newly installed spacer.

   To install idler gear proceed as follows:

   - a. Position bearings with spacer between them in idler gear.
   - b. Apply a light coat of engine oil to idler gear shaft. Position idler gear with bearings on idler shaft making certain the timing marks on the idler gear and the crankshaft gear are lined up properly when #1 piston is at top dead center.

NOTE: Early model engines used a two piece idler gear assembly. It is required to line up the timing marks on the small gear with the timing marks on the large gear when the two gears are assembled together.



1. Slot
2. Oil Hole
3. Idler Gear Shaft
4. Wrench

Figure 4. Installing Idler Gear Shaft

c. Install capscrew with washer and tighten capscrew to a torque of 95 to 105 lbs. ft.

NOTE: The specified end play of the idler gear bearing is a minimum of .001".

G. FRONT SUPPORT PLATE

1. General

The front support plate is made of steel plate and is used to support the timing gear cover. It also provides a mounting surface for the fuel injection pump mounting adaptor and the optional hydraulic pump. The front support plate is secured to the cylinder block by three lock bolts (self-locking) and three capscrews with lockwashers. The front support plate is sealed to the cylinder block with the front plate gasket.

2. Removal, Inspection, and Installation

a. Drain cooling system and remove timing gear cover. Refer to Topic 2 of this Section.

b. Remove the camshaft gear. Refer to Section 11, CAMSHAFT AND CAMSHAFT BEARINGS.

c. Remove the fuel pump drive gear. Refer to Section 4, FUEL SYSTEM.

d. Remove idler gear and idler gear shaft. Refer to Paragraph F, of this Topic.

e. Remove the crankshaft gear. Refer to Section 13, CRANKSHAFT AND CRANKSHAFT GEAR.

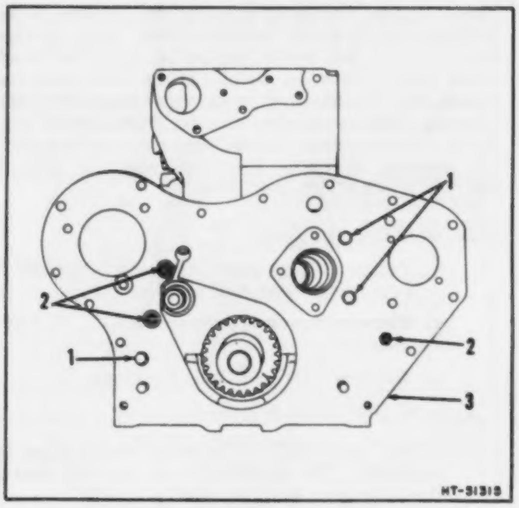
f. Remove the fuel injection pump. Refer to Section 4, FUEL SYSTEM.

g. Remove fuel pump mounting adaptor. Refer to Section 4, FUEL SYSTEM.

h. Remove lock bolts, capscrews and lockwashers, and remove front support plate from engine.

i. Inspect front support plate for damage or wear and replace if necessary.

j. Use new gaskets for the installation and install the front support plate by a direct reversal of the removal procedure. Refer to Figure 5 for the location of the lock bolts and capscrews. After the installation is completed fill the cooling system.



1. Capscrew
2. Lock Bolt
3. Front Support Plate

Figure 5. Front Support Plate Capscrews and Lock Bolts Location

SECTION 9
FLYWHEEL AND RING GEAR, FLYWHEEL HOUSING AND CRANKSHAFT REAR OIL SEAL

TOPIC TITLE

1 FLYWHEEL AND RING GEAR 9.1
  A. GENERAL
  B. FLYWHEEL REMOVAL AND INSTALLATION
  C. FLYWHEEL INSPECTION
  D. FLYWHEEL RING GEAR REMOVAL, INSPECTION, AND INSTALLATION

2 FLYWHEEL HOUSING AND CRANKSHAFT REAR OIL SEAL 9.2
  A. GENERAL
  B. FLYWHEEL HOUSING REMOVAL AND INSPECTION
  C. FLYWHEEL HOUSING INSTALLATION
  D. CRANKSHAFT REAR OIL SEAL REMOVAL AND INSTALLATION

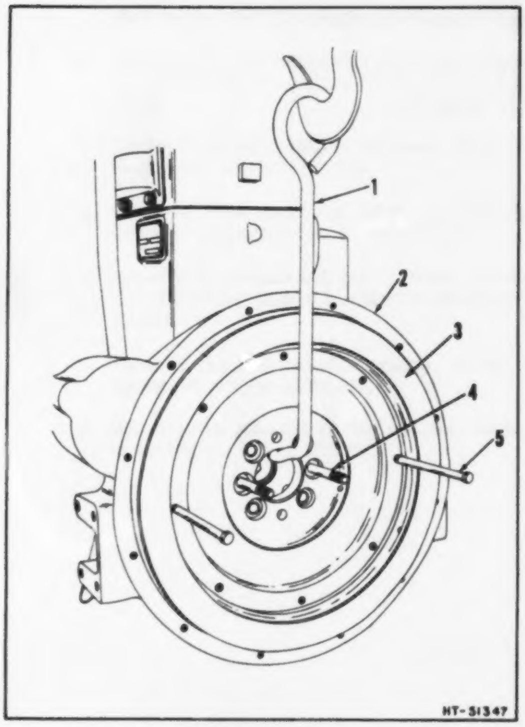
TOPIC 1. FLYWHEEL AND RING GEAR

A. GENERAL

The flywheel assembly is positioned on two dowel pins and is bolted to the flange on the rear end of the crankshaft with lock bolts. One bolt hole in the flywheel is offset and the flywheel can be attached to the crankshaft flange in only one position. A starter ring gear is shrunk on the rim of the flywheel.

B. FLYWHEEL REMOVAL AND INSTALLATION

1. Remove engine power take-off clutch; remove starter.
2. Remove flywheel lock bolts attaching flywheel to crankshaft flange. For ease of flywheel removal, install two guide pins in opposite holes in crankshaft flange and perpendicular to the dowel pins.



1. Lifting Hook
2. Flywheel Housing
3. Flywheel
4. Guide Pin
5. Capscrew (handle)

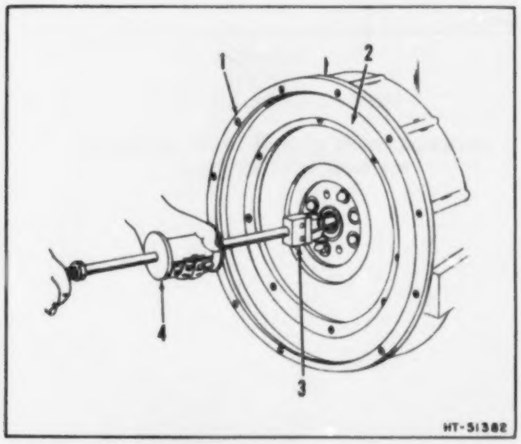
Figure 1. Typical Flywheel Removal

3. Install two long capscrews, to serve as handles, in opposite holes of flywheel face. Pull on handles and remove flywheel (Figure 1).

NOTE: If flywheel cannot be removed with a direct pull and shaking on the handles, it may be necessary to remove the flywheel housing cover from the front side of the housing and pry flywheel loose with a suitable brass bar. Turn flywheel and tap exposed part at intervals until flywheel can be removed.

4. Inspect the engine clutch shaft pilot bearing located in bore of flywheel. The bearing is lubricated when it is assembled. If the bearing is to be removed, it may be pulled from the flywheel with a tool similar to the one illustrated in Figure 2 if the flywheel is mounted on the engine, or it may be driven from the flywheel if the flywheel is removed. When installing a new bearing, use a driver or tube that will provide for driving against the bearing outer race; then drive the bearing into position in the flywheel. Lubricate pilot bearing.
5. Thoroughly clean and inspect flywheel. Refer to Paragraph C of this Topic.

NOTE: For removal, inspection, and installation of ring gear, refer to Paragraph D of this Topic.



1. Flywheel Housing
2. Flywheel
3. Pilot Bearing Removal Tool
4. Slide Hammer

Figure 2. Removing Clutch Shaft Pilot Bearing From Flywheel

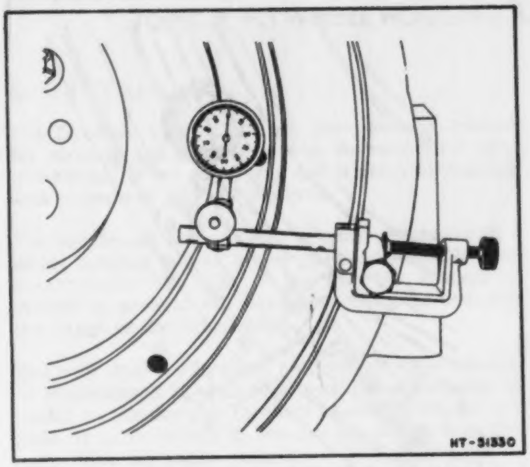


Figure 3. Measuring Run-Out of Flywheel Face

6. For ease in installing flywheel, install two guide pins (Figure 1).

7. Install flywheel by reversing the removal procedure being careful not to damage the rear oil seal.

8. After flywheel is assembled to the crankshaft, tighten the flywheel lock bolts to a torque of 95 to 105 lbs. ft.

9. Attach a dial indicator to the flywheel housing and check flywheel face for run-out (Figure 3). Pry flywheel to the rear, to eliminate crankshaft end ply, otherwise dial indicator reading will not be accurate. Flywheel face run-out must not exceed .0005" maximum total indicator reading per inch of flywheel diameter.

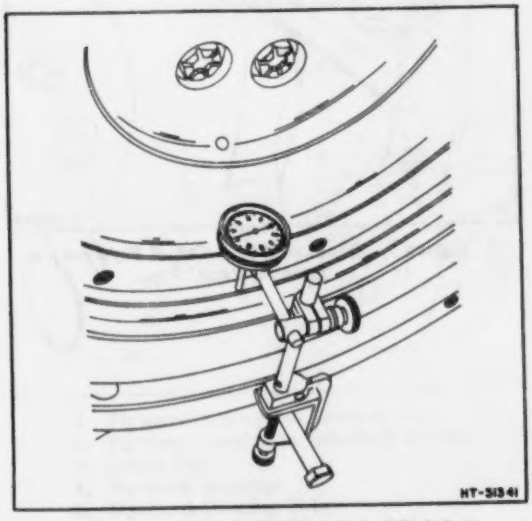


Figure 4. Measuring Run-Out of Driving Ring Bore

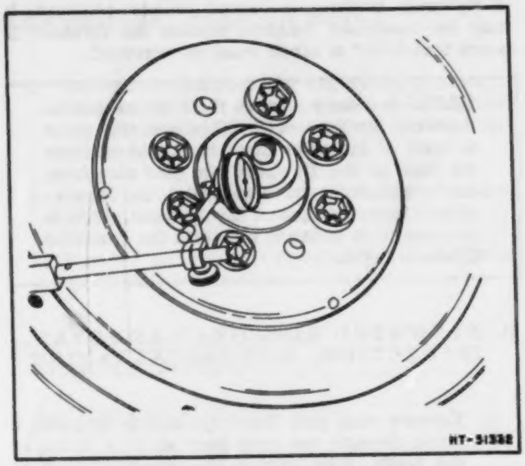


Figure 5. Measuring Run-Out of Pilot Bearing Bore

10. Readjust dial indicator so that the stem will ride on flywheel driving ring bore (Figure 4). The eccentricity of the driving ring bore must not exceed .005" maximum total indicator reading.

NOTE: Eccentricity between driving ring bore and pilot bearing bore must not exceed .008" total indicator reading.

11. Attach dial indicator to the flywheel housing and check pilot bearing bore for run-out (Figure 5). Eccentricity of pilot bearing bore must not exceed .005" maximum total indicator reading.

12. Attach dial indicator to flywheel and check flywheel housing bore for run-out (Figure 6). The bore run-out must not exceed .008" total indicator reading.

13. Readjust dial indicator to check flywheel housing face for run-out (Figure 7). The face run-out must not exceed .008" total indicator reading.

C. FLYWHEEL INSPECTION

Check to see if flywheel surface is scored or heat-checked; flywheel should be machined smooth or replaced if either condition exists. It is very important that all burrs and nicks be removed from the flywheel surface that fits against the crankshaft flange. If this surface is not smooth and true, the flywheel may have a slight wobble which will result in improper clutch operation and engine vibration.

If flywheel surface is scored or heat-checked, it may be machined smooth; replace the flywheel if more than 1/16" of stock must be removed.

NOTE: In cases where it is necessary to machine the face of the flywheel, the same amount of material must be machined from the face of the flywheel rim (and also from the counterbore, if applicable) as is machined from the face of the flywheel. This is necessary in order to maintain the specified flywheel depth.

D. FLYWHEEL RING GEAR REMOVAL, INSPECTION, AND INSTALLATION

1. Remove ring gear from flywheel by grinding a notch through the ring gear at root of one of the teeth; then expand the ring and drive it from its position. Do not attempt to remove ring gear without first expanding it.

2. Inspect flywheel ring gear for general condition and wear. Replace ring gear if it is not in good condition.

3. To install a flywheel ring gear, proceed as follows:

   a. The ring gear is shrunk onto the flywheel by uniformly heating the gear to approximately 300° - 325°F (dull red heat visible in the dark), then placing in position on the flywheel which is at room temperature.

NOTE: Do not heat the ring gear to a bright red as the heat-treatment of the gear will be destroyed.

   b. After heating, start ring gear on the flywheel so that when the flywheel is installed the chamfered ends of the teeth on the ring gear will face the cylinder block. The ends of the teeth engage with the pinion of the starter.

   c. Drive ring gear down tight against shoulder on the flywheel. Allow ring gear to cool slowly; do not cool with water.

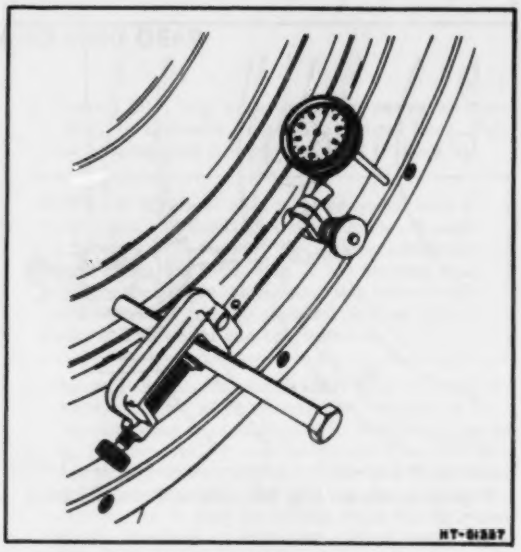


Figure 6. Measuring Run-Out of Flywheel Housing Bore

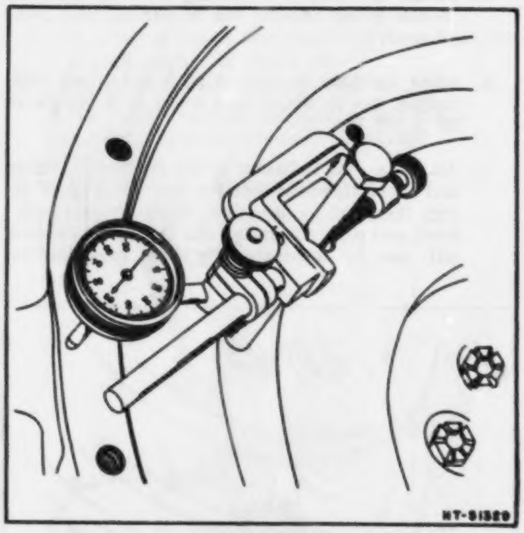


Figure 7. Measuring Run-Out of Flywheel Housing Face

TOPIC 2. FLYWHEEL HOUSING AND CRANKSHAFT REAR OIL SEAL

A. GENERAL

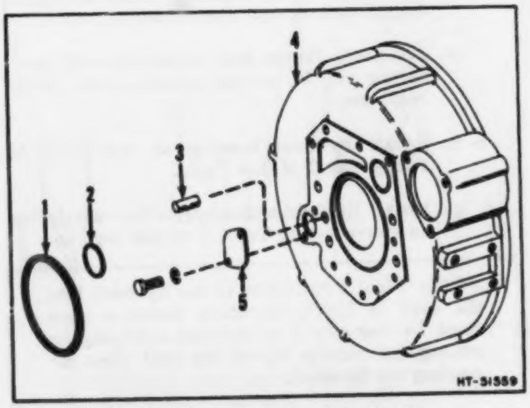
The flywheel housing is a one piece casting, ribbed for strength and is positioned on the rear of the cylinder block on two dowel pins and is secured in place with capscrews and lockwashers.

The crankshaft rear oil seal is pressed into the flywheel housing and is of the spring-loaded lip type construction. The I. D. of the seal has a layer of rubber to prevent oil leakage between the seal and the flange on the crankshaft.

The only time the flywheel housing requires service or replacement is when it is cracked or damaged. In order to remove the flywheel housing from the engine, it is necessary to remove the engine from the unit. With the engine mounted on an engine stand or supported on blocks, remove the flywheel housing following the procedure listed in the following paragraph.

B. FLYWHEEL HOUSING REMOVAL AND INSPECTION

1. Remove power take-off clutch.
2. Remove flywheel from the engine as instructed in Topic 1 of this Section.
3. Remove capscrews securing the oil pan to the flywheel housing.
4. Remove capscrews securing flywheel housing to the cylinder block. Tap housing with a soft-headed hammer to break it loose from the housing dowels; remove the housing.



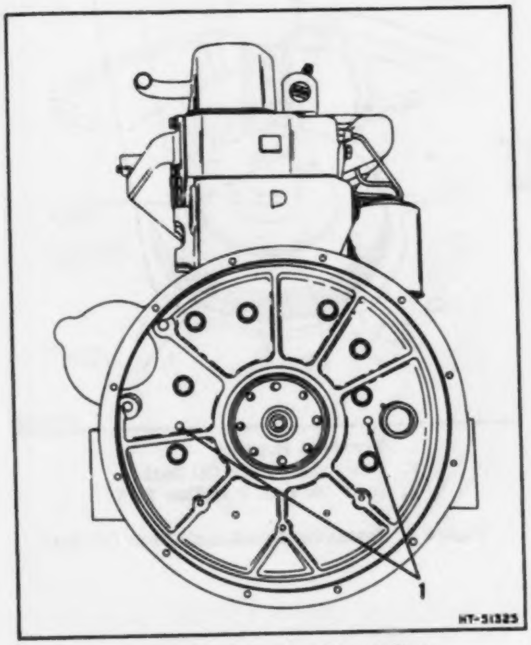
1. Flywheel Housing to Block O-ring
2. Flywheel housing to Camshaft O-ring
3. Dowel Pin
4. Flywheel Housing
5. Flywheel Housing Cover

Figure 1. Flywheel Housing

5. Thoroughly clean housing with cleaning solvent. Remove flywheel housing-to-block O-ring and the flywheel housing-to-camshaft O-ring from the housing.
6. Inspect housing for cracks and other damage; repair or replace housing if damaged.
7. Remove and discard crankshaft rear oil seal and install a new seal.

C. FLYWHEEL HOUSING INSTALLATION

1. Clean rear of cylinder block.
2. Position two new flywheel housing-to-block O-rings in the grooves of the housing.
3. Assemble flywheel housing to the rear of the block by reversing the removal procedure. Tighten the attaching housing capscrews to a torque of 95-105 lbs. ft. Tighten the capscrews securing the rear of the oil pan to the flywheel housing to a torque of 28-33 lbs. ft.
4. Install the flywheel as instructed in Topic 1 of this Section.



1. Flywheel Housing Dowel Pins

Figure 2. Flywheel Housing Installed

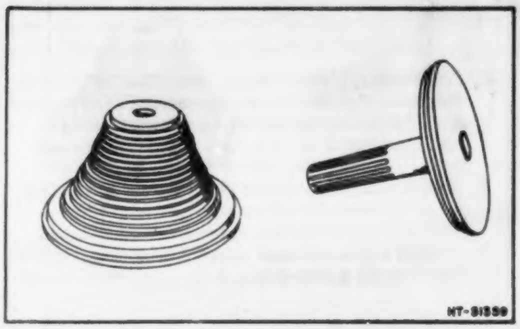
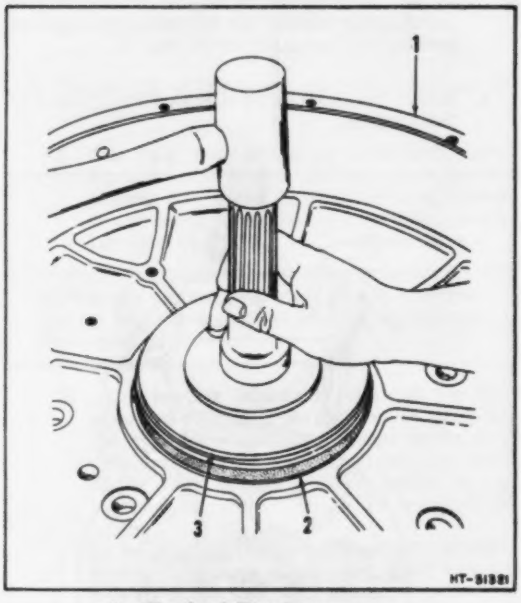


Figure 3. Crankshaft Rear Oil Seal Removal and Installing Tool

5. Check the run-out of the flywheel face, flywheel driving ring bore, pilot bearing bore, flywheel housing bore, and flywheel housing face.

6. Complete the rest of the installation by reversing the removal procedure.



1. Flywheel Housing
2. Crankshaft Rear Oil Seal
3. Rear Oil Seal Installer Tool

Figure 4. Installing Crankshaft Rear Oil Seal

D. CRANKSHAFT REAR OIL SEAL REMOVAL AND INSTALLATION

The crankshaft rear oil seal, which is a press fit in the flywheel housing, is a spring-loaded, single-lip type.

1. Crankshaft Rear Oil Seal Removal

   a. Remove all components and assemblies required for the removal of the flywheel housing as described in Paragraph B of this Topic.

   b. Place flywheel housing on a bench with the O-rings side up. Drive out the old seal from the housing with an oil seal remover similar to the one illustrated in Figure 3.

2. Crankshaft Rear Oil Seal Installation

   a. Clean oil seal bore in the flywheel housing.

   b. The O.D. of the seal has a layer of red-colored sealant which eliminates the use of a sealing compound on the O.D. of the seal prior to pressing it into the flywheel housing.

   c. Position seal (Figure 4) squarely with bore in housing and, using a seal installer, carefully drive seal into flywheel housing until it is seated against the seal stop in the bore.

NOTE: The seal must be installed with sealing lip of seal directed toward the cylinder block.

   d. Make certain the crankshaft flange on which the seal rides is free from nicks or burrs. Polish with crocus cloth if necessary.

   e. Lubricate flange and sealing lip with clean engine oil. Do not use grease, soap, white lead, etc.

   f. Install flywheel housing as instructed in Paragraph C of this Topic.

   g. Install flywheel and complete the installation as instructed in Topic 1 of this Section.

NOTE: Final installation of the flywheel into the seal is blind, therefore extreme care must be exercised to prevent crimping or cutting the sealing lip of the seal when installing the flywheel.

SECTION 10.
LUBRICATION SYSTEM

TOPIC **TITLE**

1 GENERAL 10.1

2 OIL PAN 10.2
- A. GENERAL
- B. OIL PAN REMOVAL AND INSPECTION
- C. OIL PAN INSTALLATION

3 OIL PRESSURE PUMP 10.3
- A. GENERAL
- B. OIL PRESSURE PUMP REMOVAL
- C. OIL PRESSURE PUMP DISASSEMBLY
- D. CLEANING AND INSPECTION OF OIL PUMP PARTS
- E. OIL PRESSURE PUMP ASSEMBLY
- F. OIL PRESSURE PUMP INSTALLATION

TOPIC 1. GENERAL

The lubrication system is so designed that the engine can be operated at up to a 15° angle. The engine is lubricated by a gear type oil pump which is driven by a gear on the camshaft. An oil pump pressure relief valve is set to relieve when the discharge pressure exceeds 82 to 98 psi and will by-pass oil back to the suction side of the oil pump.

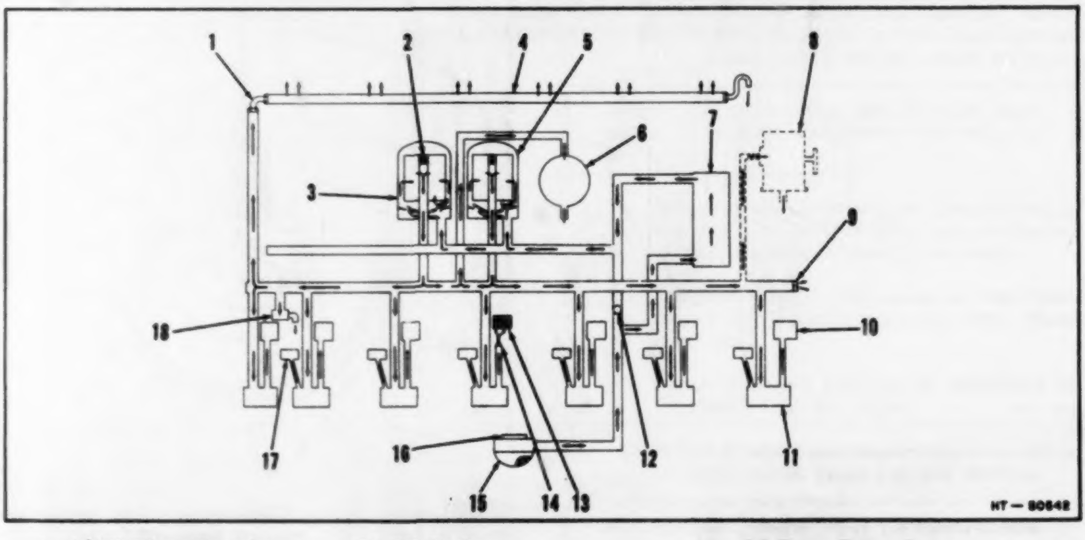
Oil pressure, at normal operating temperature, should be 30-55 psi at full throttle. The oil filter contains an oil filter by-pass valve. If the oil filter becomes clogged, or if in cold weather the oil is too thick to circulate freely through the filter, the valve opens and the oil by-passes the filter and is forced directly into the main oil gallery.

Stabilized oil pressure is maintained within the engine by an oil pressure regulating valve located in the main oil gallery of the cylinder block. Excess oil, by-passed through this valve, returns to the oil pan. For removal, cleaning, and installation of the oil pressure regulating valve, refer to LUBRICATION SYSTEM Topic, Section 1.

The oil pressure pump draws oil from the sump, through the suction screen, then circulates the oil, under pressure, through the oil cooler (if applicable) and oil filters. The oil then flows into the main oil gallery. Oil passages convey the oil from the main oil gallery to the main bearings, connecting rod bearings, and camshaft bearings. The piston pins and the connecting rod bushings are lubricated through a funnel shaped cavity located in the top of each connecting rod. There is a sufficient quantity of oil from splash and spray within the engine so that each cavity catches enough oil to keep it full and feeds the oil into the connecting rod bushing. An oil line extending from the top of the cylinder head (at the flywheel end) to the end of the rocker arm shaft, supplies oil to the rocker arm assembly. Oil returning by gravity from the cylinder head to the oil pan lubricates the push rods and valve lifters.

The cylinder walls are lubricated by splash and spray created by the revolving crankshaft and connecting rods. The gear train is splash lubricated by oil thrown by the gears.

If the engine is equipped with a turbocharger, oil is conveyed to and returned from the unit through external oil lines. If the engine is equipped with an air compressor, oil is conveyed to the unit through an external oil line and is returned to the engine through an opening in the hollow mounting bracket.



1. 1/16" Elbow Restrictor
2. Relief Valve
3. Drain Back-Check Valve
4. Rocker Arm Shaft
5. Lube Oil Filter
6. Turbocharger
7. Oil Cooler
8. Air Compressor (optional)
9. 1/16" Restrictor
10. Cam Bearing
11. Main Bearing
12. Gallery Plug
13. Oil Pump Drive Gear
14. 3/32" Restriction
15. Oil Pump
16. Relief Valve (Dumps internally)
17. Rod Bearing
18. Oil Pressure Regulating Valve

Figure 1. Lubrication Oil Flow Schematic Diagram (Model 3500 Engine)

Figure 2. Not applicable.

Not applicable.

TOPIC 2. OIL PAN

A. GENERAL

The oil pan is the reservoir for the engine lubricating oil and contains a drain plug on each side of the pan for periodic draining of the oil. The oil pan is sealed to the cylinder block and timing gear cover by a gasket. The front of the oil pan is secured to the timing gear cover and the side rails are secured to the cylinder block. The rear of the oil pan is sealed by being pressed against the lower portion of the flywheel housing O-ring and is secured to the flywheel housing. Besides sealing the rear of the oil pan, the upper part of the flywheel housing O-ring prevents oil leakage between the flywheel housing and the rear of the cylinder block.

B. OIL PAN REMOVAL AND INSPECTION

1. Remove the drain plug from the oil pan and allow the oil to drain.
2. Remove oil pan capscrew securing voltage regulator ground lead wire and move wire out of the way.
3. Remove remaining capscrews and lockwashers securing oil pan to flywheel housing, timing gear cover, and cylinder block.
4. Jar the oil pan, drop the rear end of the pan first, and remove oil pan.

NOTE: Take care not to damage O-ring in front side of the flywheel housing.

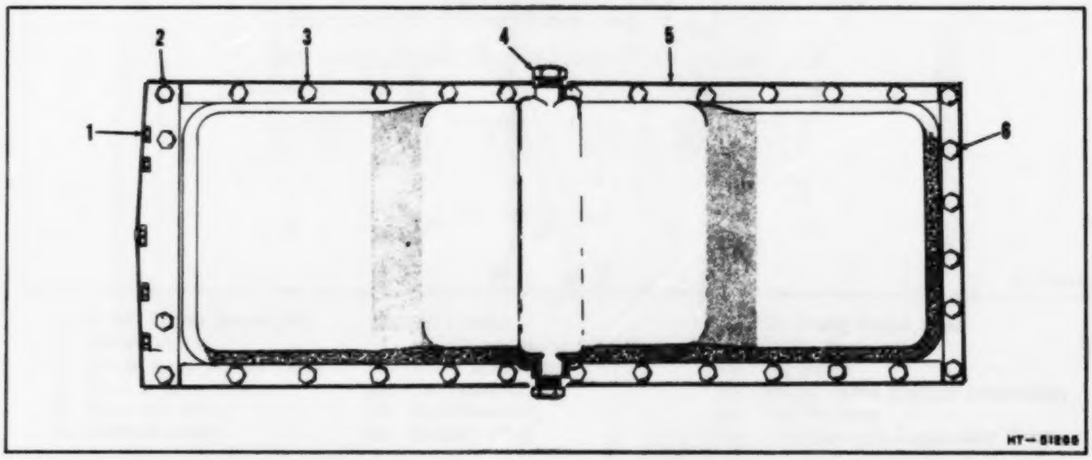
5. Wash oil pan in cleaning solvent and clean gasket sealing surfaces on oil pan and cylinder block.
6. Inspect oil pan for evidence of cracks or other damage. Inspect drain plug boss for evidence of leakage. Make necessary repairs or replace oil pan if necessary. Make certain O-ring in front of flywheel housing is in perfect condition.

NOTE: The flywheel housing O-ring should be replaced when the engine is overhauled. If the engine is not overhauled, inspect lower portion of the O-ring to make certain it is in perfect condition. If the O-ring has to be replaced, it is necessary to remove the flywheel housing. Refer to Section 9 for flywheel housing removal.

C. OIL PAN INSTALLATION

1. Cement a new gasket set to the rails of the oil pan.

NOTE: On the early models of engines, the center portion of the rear section of the oil pan gasket is not supported by the oil pan rails. Occasionally this loose gasket material deteriorates and can accumulate on the oil pump screen. Whenever an oil pan is removed from the engine, the center portion of the gasket which is unsupported should be cut out of the replacement gasket before the oil pan is installed on the engine.



1. Flywheel Housing Capscrew (3/4" long)
2. Rear Rail Capscrew (7/8" long)
3. Side Rail Capscrew (7/8" long)
4. Drain Plug
5. Oil Pan
6. Timing Gear Cover Capscrew (1" long)

Figure 1. Oil Pan and Location of Capscrews

2. Before installing the oil pan, place a small quantity of non-hardening sealing compound in the corners formed by the flywheel housing and the cylinder block rails and also at the front where the front support plate contacts the cylinder block rails.

3. For ease of installing the oil pan, make up two guide studs and screw them into the diagonal corners of the cylinder block. Also have available a greased sheet of shim stock larger than the rear area of the oil pan. The greased sheet of shim stock is placed against the O-ring in the lower portion of the flywheel housing to protect the O-ring from damage when the oil pan is installed.

> NOTE: If the engine is out of the unit at the time of repair, loosen the capscrews securing the front support to the cylinder block for additional clearance for the front of the oil pan and the greased sheet of shim stock will not be necessary.

4. Position the oil pan with the front end up and mount the oil pan on the guide studs. Hold it in position by inserting a capscrew and lockwasher in each corner, but do not tighten them so that the oil pan cannot be shifted. Carefully ease out the greased sheet of shim stock protecting the O-ring in the flywheel housing.

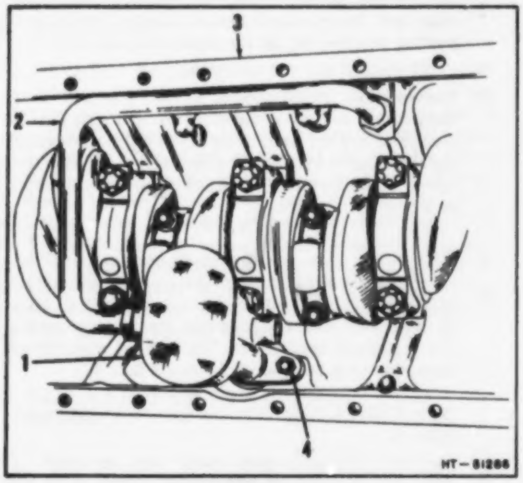
5. Remove the guide studs. Install the 3/4" long capscrews and lockwashers which hold the rear flange of the oil pan to the flywheel housing and tighten the rear corner capscrews and the two upper capscrews in the flywheel housing alternately until secure.

6. Install the 1" long capscrews and lockwashers securing the front rail of the oil pan to the timing gear cover. Install the remaining capscrews and lockwashers and the voltage regulator ground lead wire. Tighten all capscrews securely to a torque of 28 to 33 lbs. ft.

7. Install drain plug into oil pan and tighten securely.

8. Fill the oil pan to the proper level with the specified engine crankcase lubricant. Run engine and check for oil leaks.

TOPIC 3. OIL PRESSURE PUMP



1. Oil Pump
2. Discharge Tube
3. Cylinder Block
4. Lock Bolt

Figure 1. Oil Pump and Discharge Tube Location

A. GENERAL

The gear-type oil pressure pump is mounted at the center of the engine block and the oil pump helical drive gear meshes directly with a helical gear located at the center of the camshaft. The oil pump drive gear is pressed onto the drive shaft and is secured with a roll pin. A bushing is provided in the pump body to support the lower end of the drive shaft. The drive gear is pressed onto the drive shaft and rotates the idler gear.

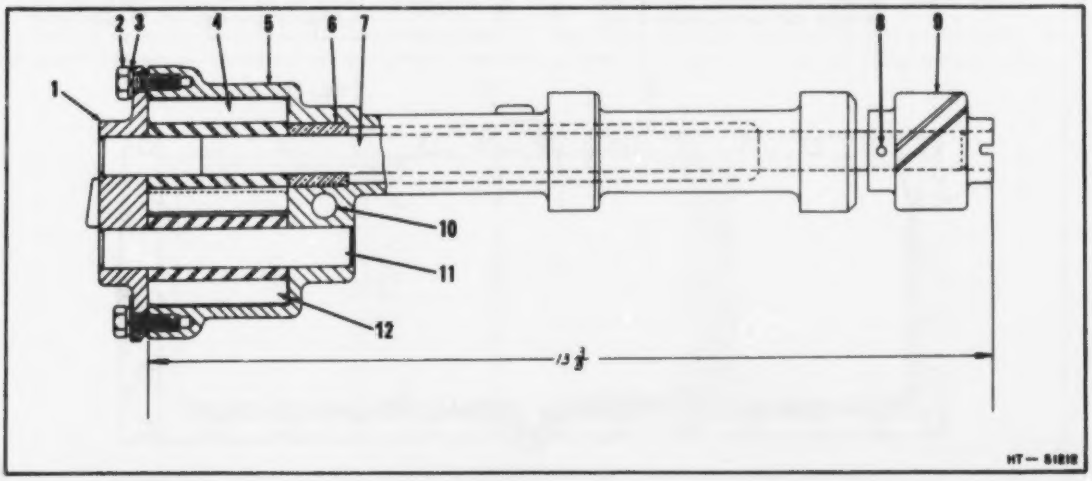
A relief valve, located in the oil pump outlet, bypasses oil back to the suction side of the oil pump when the discharge pressure exceeds 82 to 98 psi. The purpose of the relief valve is to relieve excessive discharge pressure which occurs when starting a cold engine, minimizing the wear of the oil pump gears.

B. OIL PRESSURE PUMP REMOVAL

1. Drain the engine oil.
2. Remove the oil pan.
3. Remove brass compression fittings securing oil pump discharge tube and remove discharge tube.
4. Remove lock bolt securing oil pressure pump to cylinder block and remove oil pump assembly.

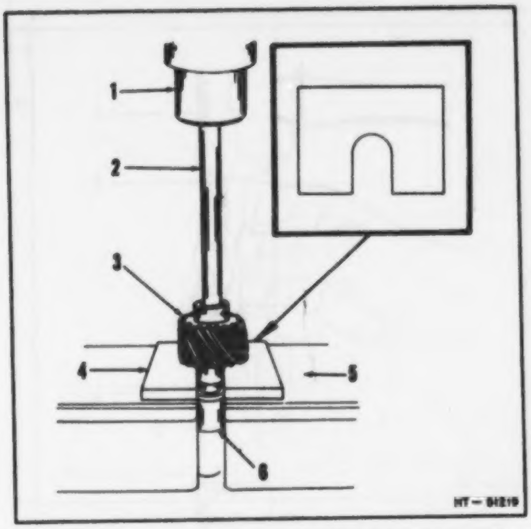
C. OIL PRESSURE PUMP DISASSEMBLY

1. Wash the oil pump assembly in clean solvent.
2. Remove the screen retainer wire and remove the oil pump screen.



1. Body Cover
2. Capscrew
3. Lockwasher
4. Driver Gear
5. Pump Body
6. Bushing
7. Drive Shaft
8. Roll Pin
9. Drive Gear
10. Relief Valve Passage
11. Idler Gear Shaft
12. Idler Gear

Figure 2. Oil Pump - Sectional View



1. Press Ram
2. Rod
3. Oil Pump Drive Gear
4. Drive Gear Removal Tool
5. Press Base Plate
6. Oil Pump Assembly

Figure 3. Removing Drive Gear from Oil Pump Drive Shaft

3. Drive out the roll pin securing the pump drive gear to the drive shaft.

4. To prevent damage to the drive gear teeth, do not remove gear from the drive shaft with a gear puller. Press the drive gear from the shaft with the tool illustrated in Figure 3.

5. Remove the capscrews and lockwashers securing the pump cover to the body assembly and remove the pump cover.

> NOTE: Some of the early model oil pumps have a dowel pin thru the cover, but this pin is eliminated on the current oil pumps.

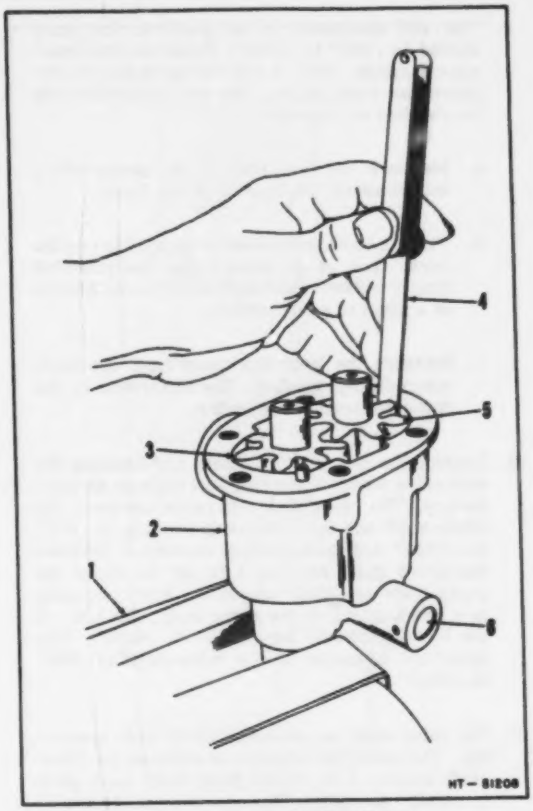
6. Remove the pump body driver gear and drive shaft from the body assembly.

7. Remove pump idler gear from idler shaft.

8. Depress relief valve spring and retainer with two screwdrivers or an improvised two-prong tool. Drive out the roll pin and remove spring retainer, spring, and relief valve piston.

D. CLEANING AND INSPECTION OF OIL PUMP PARTS

1. Wash all the oil pump components in clean solvent and thoroughly inspect all the parts before reassembling the oil pump. The principal wearing parts of the oil pump are the drive gear, the driver gear, and the idler gear. If dirt and sludge have been allowed to accumulate in the lubricating system, oil pump gear wear may be rather pronounced in a comparatively short time. When the oil has been kept clean and the oil filters have been properly serviced, the wear on these parts should be slight.



1. Vise
2. Oil Pump Body
3. Driver Gear
4. Feeler Gauge
5. Idler Gear
6. Relief Valve Location

Figure 4. Checking Radial Clearance

2. Inspect the pump gear teeth, the inside of the pump body, and the inner face of the cover for wear or scoring. The gear teeth, the inside of the pump body, and the inner face of the cover must be smooth, having no scratches, score marks, or rough spots.

3. The radial clearance between the pump gears and the pump body should be .00075" to .00175". When the radial clearance exceeds .006" it will be necessary to replace the worn parts.

4. The specified back lash between the driver gear and the idler gear should not exceed .005" to .006".

5. The end clearance of the gears in the pump should be .002" to .0045". When the end clearance exceeds .007" it will be necessary to replace the worn parts. The end clearance may be checked as follows:

   a. Measure the thickness of the gears with a micrometer. Make note of the figure.

   b. Place a depth micrometer in position on the cover face of the pump body, and pressing firmly measure the depth of the counterbore at a point of gear contact.

   c. Subtract the gear thickness from the depth micrometer reading. The difference is the end clearance of the gears.

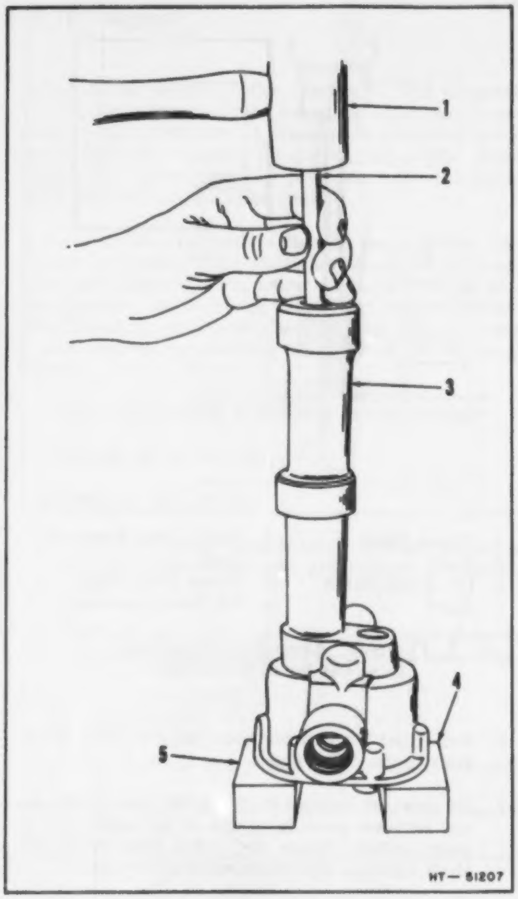
6. Inspect the pump drive shaft and bushing for excessive wear or scoring and replace as necessary. The specified clearance between the drive shaft and the pump body bushing is .001" to .0035" and the specified clearance between the drive shaft and the I. D. at the top of the pump body is .0015" to .003". After pressing in a new bushing in the pump body, the I. D. of the bushing should be .6235" to .6255". The specified diameter of the drive shaft is .622" to .6225".

7. The idler shaft is pressed into the body assembly. The specified clearance between the idler shaft and the I. D. in the pump body idler gear is .0005" to .003". The specified diameter of the idler shaft is .618" to .6185". The specified I. D. in the pump body for the idler shaft is .616 to .617".

8. The specified clearance between the drive shaft and the I. D. in the cover is .002" to .0035". The fit between the idler shaft and the cover is from .000" to .0015" loose. The I. D. in the cover for the drive shaft is .6195" to .6205" and the I. D. in the cover for the idler shaft is .6185" to .6195".

9. Clean and inspect relief valve piston. The piston must slide smoothly in the bore of the relief valve body. When the piston or the bore of the valve body shows excessive wear or roughness, a new relief valve assembly must be installed. The clearance between the O. D. of the piston and the bore in the pump body should be .001" to .0025".

10. Inspect and thoroughly clean the oil pump screen before installing it on the oil pump assembly.



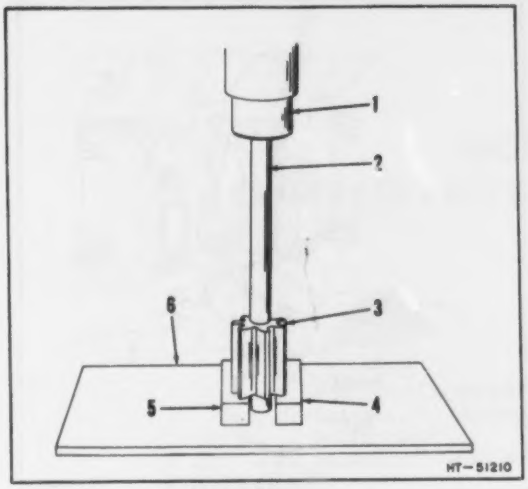
1. Hammer
2. Rod
3. Pump Body
4. Plate
5. Plate

Figure 5. Removing Bushing from Oil Pump Body

E. OIL PRESSURE PUMP ASSEMBLY

The drive shaft requires a roll pin for the pump drive gear. Lubricate the gears, bushing, and shafts with clean engine oil and assemble the oil pump as follows:

1. Using a suitable press, install the pump body driver gear onto the pump drive shaft. The end of the driver gear must be located 3/4", plus zero, minus 1/64", from the end of the drive shaft.

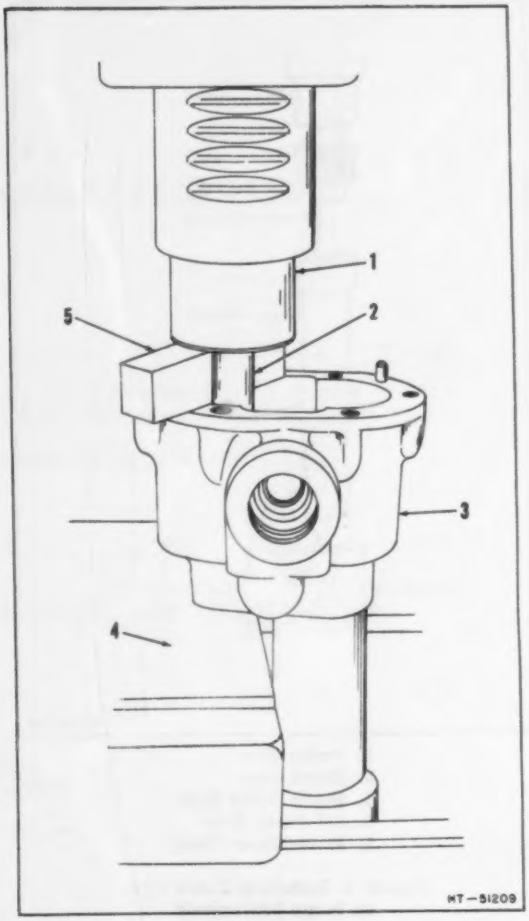


1. Press Ram
2. Oil Pump Drive Shaft
3. Driver Gear
4. 3/4" Keystock
5. 3/4" Keystock
6. Press Base Plate

Figure 6. Installing Driver Gear on Pump Drive Shaft

2. Install the idler shaft into the pump body, so that the end of the idler shaft protrudes 3/4" from the bottom of the pump body.
3. If a new bushing is used, press in bushing so that the end of the bushing is flush to .004" below the surface inside the pump body. The O.D. of the bushing is 1.0015" to 1.002" and the I.D. of the bore in the lower pump body is 1.000" to 1.0005". The I.D. of bushing after pressing it into pump body is .6235" to .6255".
4. Install the pump drive shaft and gear into the oil pump body.
5. Using a suitable press install the pump drive gear onto the drive shaft, aligning the hole in the drive shaft with the hole in the pump drive gear, and install the roll pin to secure the pump drive gear to the drive shaft.

NOTE: If a new drive shaft or drive gear is being used, support the lower end of the drive shaft on the press base plate, and press the drive gear onto the drive shaft so that the upper face of the gear is 13-3/8" (Figure 2) from the bottom of the pump body. Drill a .125" to .129" hole (90° from old hole in shaft) through the drive shaft and in line with the hole in the drive gear, or drill through the gear and the shaft when a new gear is used. Drill the hole 7/32" from the end and in the center of the gear. Install the roll pin to secure the drive gear to the pump drive shaft.



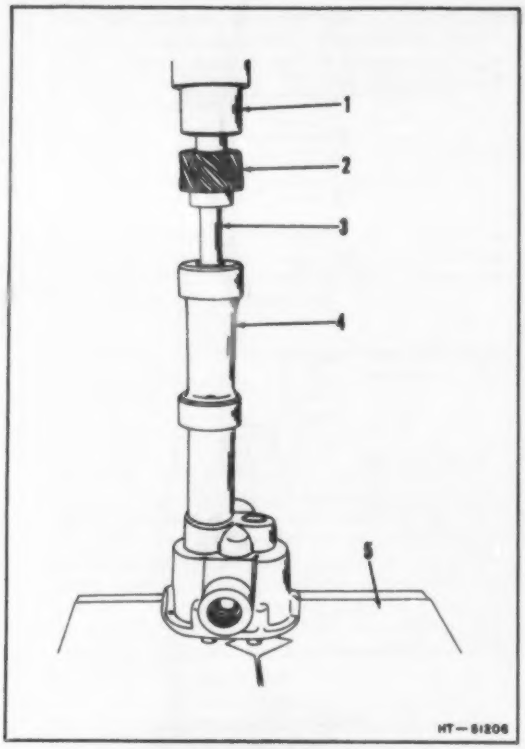
1. Press Ram
2. Idler Shaft
3. Oil Pump Body
4. Press Base Plate
5. 3/4" Keystock

Figure 7. Installing Pump Idler Shaft

6. Install the pump body idler gear onto the idler shaft.
7. Install the pump body cover and secure with capscrews and lockwashers. Tighten the capscrews to a torque of 9 to 11 lbs. ft.

NOTE: One hole in the cover is offset and the cover can only be installed in one position.

8. Install relief valve piston, spring, and spring retainer. Depress relief valve spring and retainer with two screwdrivers or an improvised



1. Press Ram
2. Drive Gear
3. Pump Drive Shaft
4. Oil Pump Body
5. Press Base Plate

Figure 8. Installing Drive Gear on Pump Drive Shaft

two-prong tool. Insert a nail or pin less than 3/16" O. D. in roll pin hole. Hold retainer with nail or pin until roll pin is installed.

9. Make certain the assembled oil pump will turn without binding before proceeding to attach it to the engine.

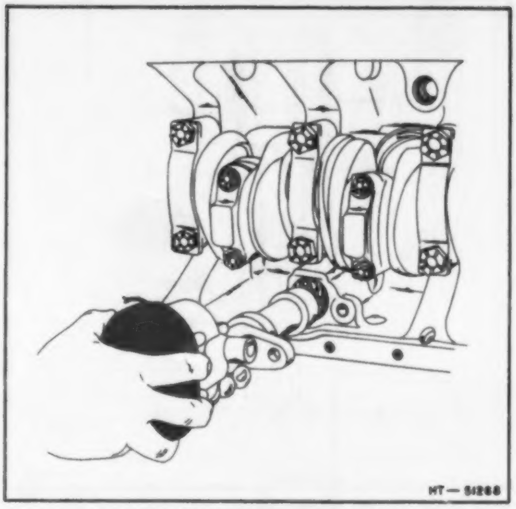


Figure 9. Installing Oil Pump in Cylinder Block

10. Install the oil pump screen on the pump assembly so that the screen does not project more than 1-3/16" from the groove on the cover. Secure the screen with the retainer wire.

F. OIL PRESSURE PUMP INSTALLATION

1. Lubricate gear and insert oil pump assembly into bore in the center of the cylinder block with the drive gear in mesh with the camshaft gear, and install oil pump with lock bolt (Figure 1). Tighten bolt to a torque of 44-49 lbs. ft.
2. Position brass fittings and install oil discharge tube to cylinder block and oil pump assembly; tighten fittings securely.
3. Continue installation of oil pan and new oil pan gasket by following procedure described in Topic 2 of this Section.
4. Fill the engine oil pan to the proper level with the specified engine crankcase lubricant.

SECTION 11
CAMSHAFT AND CAMSHAFT BEARINGS

TOPIC TITLE

1 CAMSHAFT 11.1
    A. GENERAL
    B. CAMSHAFT AND CAMSHAFT GEAR REMOVAL
    C. CAMSHAFT, CAMSHAFT GEAR, AND THRUST PLATE INSPECTION
    D. CAMSHAFT GEAR AND CAMSHAFT INSTALLATION

2 CAMSHAFT BEARINGS 11.2
    A. GENERAL
    B. CLEARANCES
    C. CAMSHAFT BEARINGS REMOVAL AND INSTALLATION

3 VALVE LIFTERS 11.3
    A. GENERAL
    B. VALVE LIFTER REMOVAL
    C. VALVE LIFTER INSPECTION
    D. VALVE LIFTER INSTALLATION

TOPIC 1. CAMSHAFT

A. GENERAL

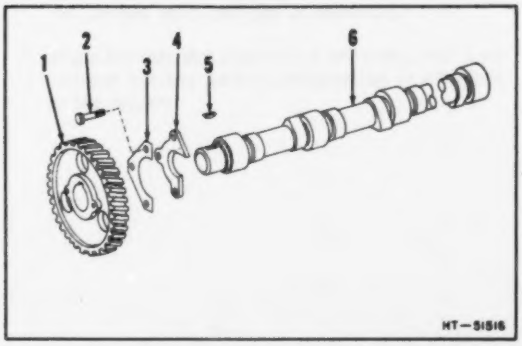
The camshaft, made of special high strength alloy iron, has journals and lobes that are hardened and precision ground, and is located in the lower half of the cylinder block on the left hand side of the engine. A hole is drilled thru the rear journal of the crankshaft to prevent the possibility of a hydrostatic lock between it and the flywheel housing. A thrust plate is provided between the camshaft gear and shoulder of the first journal to position the camshaft in the cylinder block. The camshaft gear is positioned on the camshaft by a key and secured in place by a press fit. The camshaft gear which is driven by the crankshaft gear, drives the optional hydraulic pump drive gear. A spiral gear located at the center of the camshaft drives the oil pump.

B. CAMSHAFT AND CAMSHAFT GEAR REMOVAL

The camshaft gear may be removed without removing the camshaft from the engine, however, to prevent possible damage to the oil pump drive gear and the flywheel housing when installing the gear, it is recommended that the camshaft is removed from the engine before removing and installing the camshaft gear.

The removal of the camshaft with the camshaft gear is essentially the same regardless if the engine is mounted in a unit or has been removed for overhaul. If the engine is in a unit, it is necessary to remove the oil pan, oil pump, timing gear cover and support the front of the engine with blocks for the removal of the front support. To remove the camshaft, proceed as follows:

1. Remove the components necessary to facilitate removal of the timing gear cover and remove the cover. Refer to Section 8, FRONT END AND GEAR TRAIN.



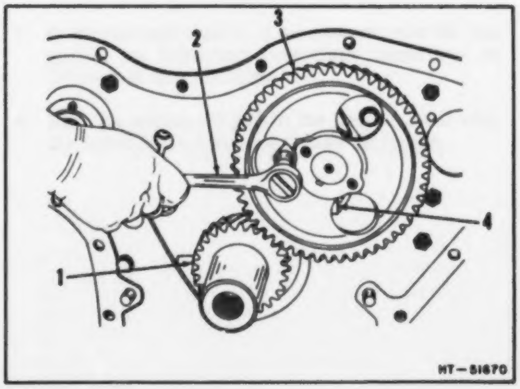
1. Camshaft Gear
2. Capscrew
3. Lock Plate
4. Thrust Plate
5. Woodruff Key
6. Camshaft

Figure 1. Camshaft and Camshaft Gear Details

2. Remove oil pan and oil pump. Refer to Section 10, LUBRICATION SYSTEM.
3. Remove the cylinder head cover, rocker arms, shaft and brackets assembly and push rods. Refer to Section 7, VALVES, VALVE OPERATING MECHANISM AND CYLINDER HEAD.
4. Before removing the camshaft from the cylinder block, check the camshaft gear backlash (Figure 9). The specified backlash between the mating gears of the crankshaft and the camshaft is .0015" to .009". New parts must be installed when the backlash between any two mating gears exceeds .015".
5. Position the camshaft gear as indicated in Figure 2 so that the camshaft thrust plate capscrews are accessible. Bend back the tabs of the lock plate and remove the capscrews.
6. Before the camshaft can be withdrawn from the cylinder block, the valve lifters must be positioned so that they do not interfere with the camshaft lobes.

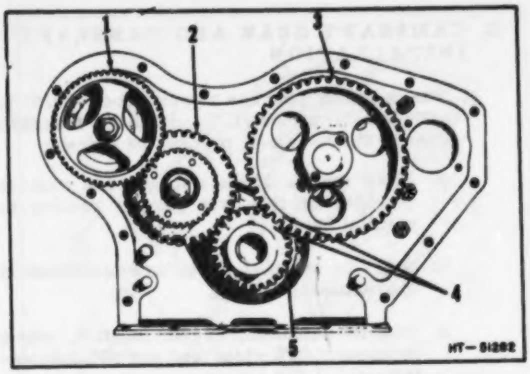
NOTE: Before removing the camshaft and camshaft gear, rotate the crankshaft until the timing marks on the crankshaft gear and the camshaft gear are aligned (Figure 3).

   a. With the engine removed from the unit for overhaul, simply lay the cylinder block on its side and push the valve lifters to their uppermost position and carefully withdraw the camshaft.



1. Crankshaft Gear
2. Wrench
3. Camshaft Gear
4. Lock Plate

Figure 2. Removing Camshaft Thrust Plate Capscrews



1. Fuel Injection Pump Drive Gear
2. Idler Gear
3. Camshaft Gear
4. Timing Marks
5. Crankshaft Gear

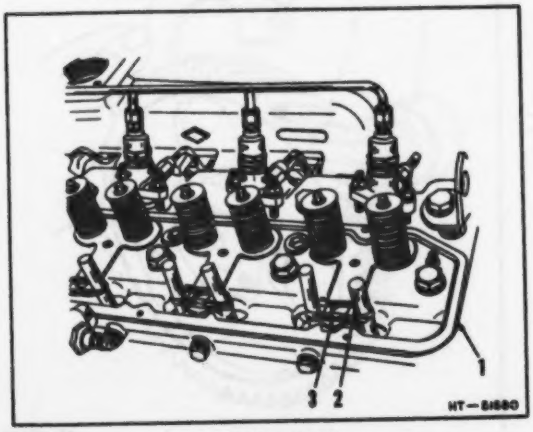
Figure 3. Crankshaft Gear and Camshaft Gear Timing Marks Aligned

> CAUTION: Be careful that the thrust plate and lock plate do not fall on the floor and that the camshaft lobes do not scratch or mar the camshaft bearings as the camshaft is withdrawn from the cylinder block.

b. If the engine is mounted in a unit, the valve lifters can be held in their uppermost position in the following manner.

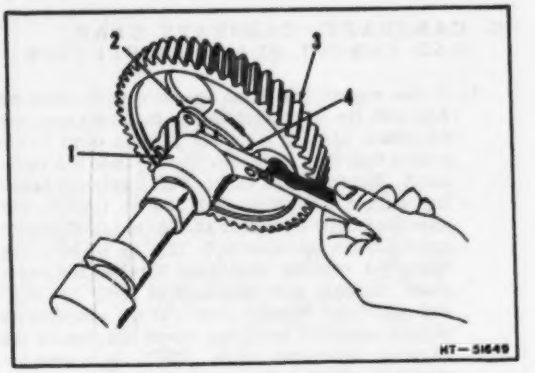
(1) Make up twelve pieces approximately 16" long of 5/8" wooden dowel rod and taper one end of each slightly.

(2) Force the tapered ends of the dowels into the valve lifters (Figure 4).



1. Cylinder Head
2. Wooden Dowel Rod
3. Rubber Band

Figure 4. Installing Wooden Dowel Rods in the Valve Lifters



1. Camshaft Journal
2. Thrust Plate
3. Camshaft Gear
4. Feeler Gauge

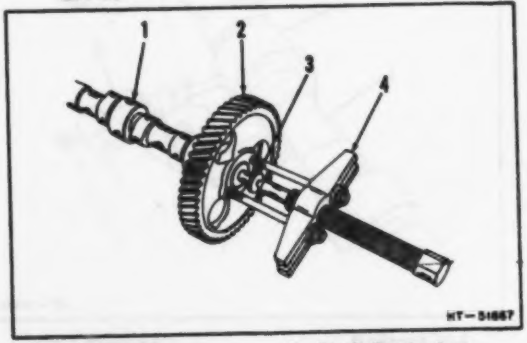
Figure 5. Checking Thrust Plate Clearance

(3) Carefully pull the exhaust and intake valve lifters for each cylinder up to their uppermost position and place a stout rubber band around the two dowels. Friction tape, wire, O-rings, or heavy string could also be used instead of rubber bands.

(4) As the camshaft is withdrawn from the cylinder block, remove the thrust plate and lock plate. Also, it may be necessary to rotate the crankshaft so that the connecting rods will not interfere with the camshaft lobes.

7. After removing the camshaft with gear from the cylinder block, check the thrust plate clearance (end play) by inserting a feeler gauge between the thrust plate and camshaft journal as illustrated in Figure 5. The specific end play is .003" to .009". If the end play exceeds the maximum wear limit of .015" with a new thrust plate, the camshaft gear must be replaced.

8. Place the camshaft in a press and force the camshaft from the gear, or remove the camshaft gear with a puller as illustrated in Figure 6.



1. Camshaft
2. Camshaft Gear
3. Shaft Protector
4. Gear Puller Tool

Figure 6. Removing Camshaft Gear

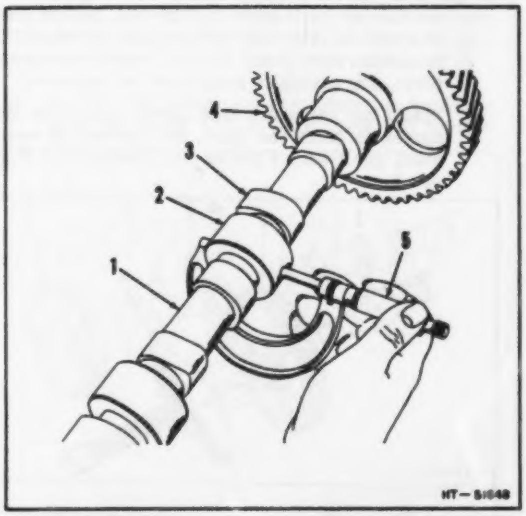
C. CAMSHAFT, CAMSHAFT GEAR, AND THRUST PLATE INSPECTION

1. If the engine has been operated with clean oil and with the correct quantity in the oil pan, the camshaft bearing journals seldom wear to the extent that it is necessary to replace the camshaft. The specified O. D. of all camshaft bearing journal diameters is 2.130" to 2.131". The specific inside diameter of the camshaft standard bearings installed is 2.133" to 2.136". The specified running clearance between the camshaft journals and bearings is .002" to .006" and must not exceed .008". If the installation of new standard bearings would not reduce the running clearance below .008", it is recommended to grind the camshaft journals to accommodate .010" undersize bearings. Likewise, if the journals are worn or scored to the extent that they will not accommodate .010" undersize bearings, the camshaft must be replaced.

2. Inspect the intake and exhaust lobes of the camshaft for roughness, scoring or excessive wear. Replace the camshaft if any of these conditions are found to exist. These conditions can be caused by inferior quality of lubricating oil, excessive valve lash adjustment, contaminated oil or the valve lifters not rotating.

3. Inspect camshaft gear for nicked, scored, or broken teeth. Replace as necessary.

4. Inspect thrust plate for wear. Replace if the wear area is rough or the wear is excessive. New thrust plate thickness is .205" to .206".



1. Camshaft
2. Camshaft Journal
3. Camshaft Lobe
4. Camshaft Gear
5. Micrometer

Figure 7. Checking Camshaft Bearing Journal

D. CAMSHAFT GEAR AND CAMSHAFT INSTALLATION

1. The camshaft gear has a press fit of .0015" to .003" on the camshaft. To install the camshaft gear to the camshaft, proceed as follows:

   a. Place the camshaft in a press with the shoulder of the first journal resting on parallel bars.

   b. Heat the gear in oil to a temperature of approximately 300° F.

   c. Coat the camshaft, at gear location, with a mixture of 50% white lead and 50% lubricating oil.

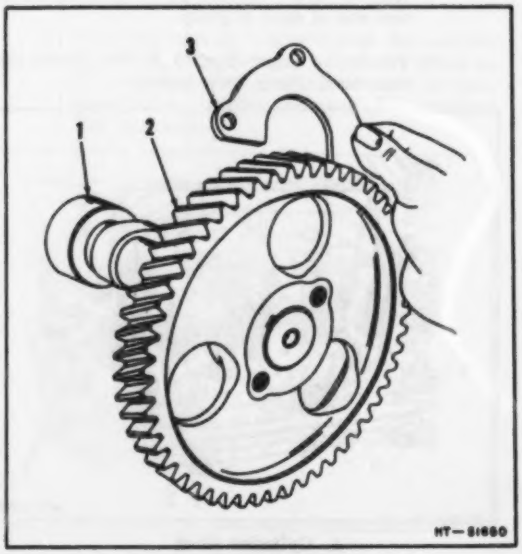
   d. Using asbestos gloves, position the gear on the camshaft and align the gear keyway with the key in the camshaft.

   e. Press the gear onto the shaft until the gear hub contacts the shoulder on the camshaft.

   f. Check the clearance between the thrust plate and bearing journal (Figure 5). The specified end play clearance is .003" to .009".

2. Check camshaft journal to bearing running clearance as described in Topic 2, of this section.

3. Oil the camshaft bearings in the cylinder block and carefully insert the camshaft. Be careful



1. Camshaft
2. Camshaft Gear
3. Thrust Plate

Figure 8. Positioning Camshaft Thrust Plate

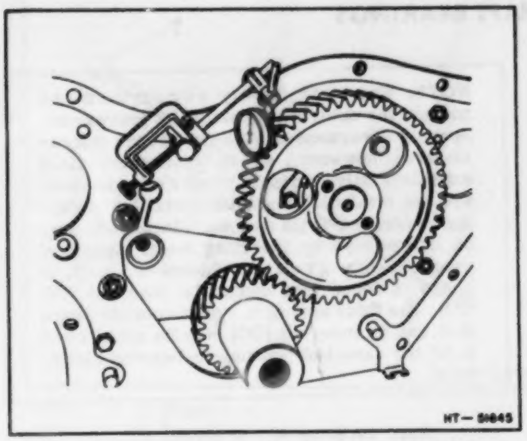


Figure 9. Checking Backlash of Camshaft Gear

not to scratch or mar the camshaft bearings. Before camshaft is completely inserted in cylinder block, position thrust plate and lock plate in place.

> NOTE: Make certain the timing marks on camshaft gear and crankshaft gear are aligned when camshaft is installed (Figure 3).

4. Install the capscrews through the lock plate and the thrust plate. Tighten the capscrews to a torque of 18 to 20 lbs. ft.

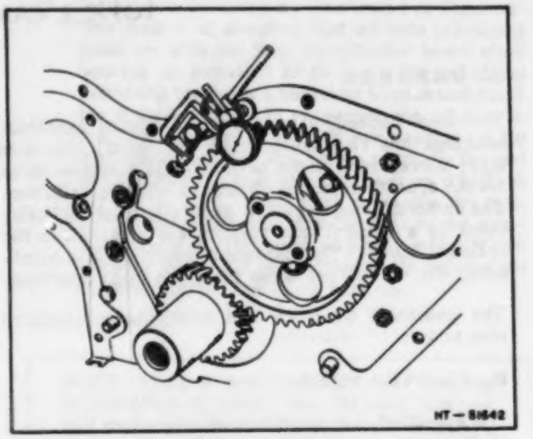


Figure 10. Checking Camshaft Gear End Play

5. Check the camshaft gear backlash. The specified backlash between the mating gears of the crankshaft and the camshaft is .0015" to .009".

6. Check camshaft gear end play (Figure 10). The specified end play is .003" to .009".

7. Reinstall all other components which were removed, by a direct reversal of the removal procedure.

TOPIC 2. CAMSHAFT BEARINGS

A. GENERAL

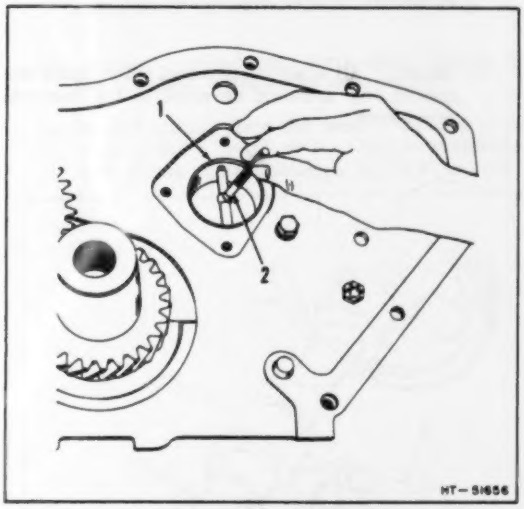
The steel backed, alloy lined, tin plated camshaft bearings are the split-clinch butt joint, precision type; therefore it is not necessary to machine them for the specified running clearance after installation. The camshaft bearings are secured in the cylinder block by a press fit and support the camshaft in the cylinder block. The camshaft bearings are lubricated through oil passages from the main bearings.

The camshaft bearings are available in standard size and .010" undersize.

B. CLEARANCES

The specified clearance between camshaft and camshaft bearings is .002" - .006". If clearance is .008" or more, new camshaft bearings must be installed. The specified diameter of camshaft bearing journals is 2.130" - 2.131". The specified inside diameter of camshaft bearings, when installed, is 2.133" - 2.136".

With camshaft removed, measure diameter of camshaft journals and inside diameter of camshaft bearings with micrometers to determine clearance.



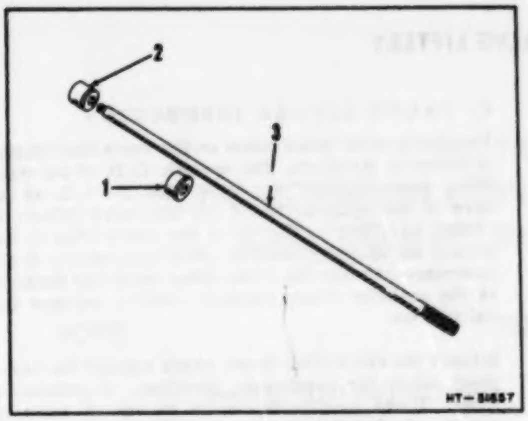
1. Camshaft Bearing
2. Telescopic Gauge

Figure 1. Measuring Inside Diameter of Camshaft Bearing

NOTE: The only factory recommended method for determining camshaft journal-to-bearing clearance is with the proper micrometers; however, as an emergency field expedient only (and when proper micrometers are not available), camshaft journal-to-bearing clearance (with camshaft installed) may be determined by inserting feeler gauges of progressively greater thickness, until a gauge is found that cannot be inserted (NO GO). The thickness of the next smaller gauge that can be inserted (GO) may be considered to be the camshaft journal-to-bearing clearance.

C. CAMSHAFT BEARING REMOVAL AND INSTALLATION

1. Remove engine from unit.
2. Remove timing gear cover. Refer to Section 8, FRONT END AND GEAR TRAIN.
3. Remove starter from engine. Refer to ELECTRICAL SYSTEM Topic, Section 1.
4. Remove flywheel and flywheel housing. Refer to Section 9, FLYWHEEL, FLYWHEEL HOUSING, AND CRANKSHAFT REAR OIL SEAL.
5. Remove the oil pan and oil pump. Refer to Section 10, LUBRICATION SYSTEM.
6. Remove the rocker arms, shaft and brackets and push rods. Refer to Section 7, VALVES, VALVE OPERATING MECHANISM AND CYLINDER HEAD.
7. Remove the camshaft. Refer to preceding Topic 1, of this section.
8. The camshaft bearing tool illustrated in Figure 2, removes the old bearing at the same time the new bearing is forced into position.
9. The camshaft bearings must be properly positioned in the cylinder block so that the oil hole in the bearing lines up with the oil hole in the cylinder block.
   a. The front camshaft bearing must be installed with the end of the bearing flush or below the front side of the cylinder block.



1. Pilot
2. Remover and Installer Tool
3. Handle

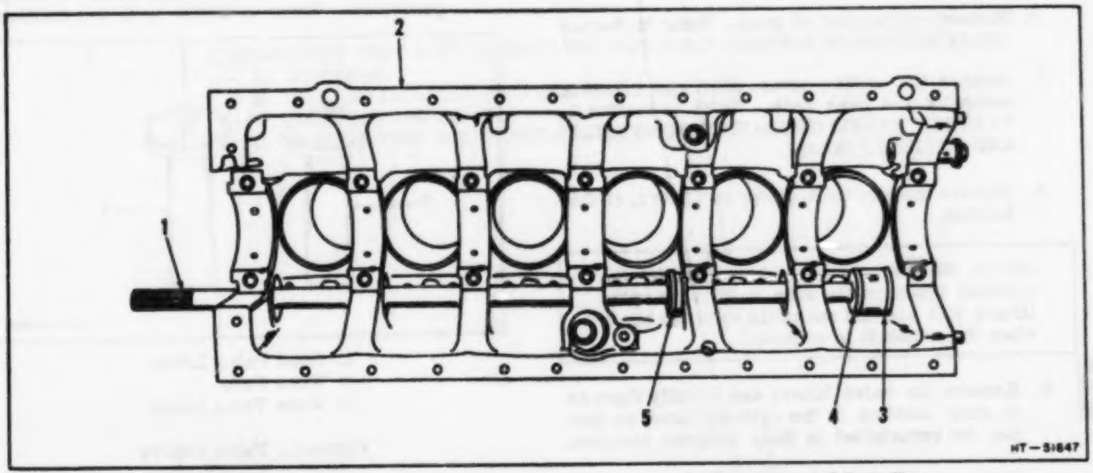
Figure 2. Camshaft Bearing Remover and Installer Tool

b. The rear and intermediate bearings are alike. The rear bearing should be installed with the end of the bearing flush with the front side of the bearing bore in the cylinder block.

10. Install new bearings as illustrated in Figure 3. One method of assuring that oil hole in bearing lines up with oil hole in cylinder block after bearing is installed is to mark the end of the installing tool with a pencil or crayon and mark the cylinder block in respect to the oil hole in the bearing bore. Install a new bearing on the installing tool and line up the mark on the end of the installing tool with the mark on the block for the oil hole. Then mark or scribe the O.D. of the installing tool thru the hole in the camshaft bearing. This enables you to watch if new bearing turns out of position while driving out old bearing and installing new one.

NOTE: When a new camshaft rear bearing is installed in place, the old rear bearing will remain partly in the cylinder block. Take a punch and collapse the old bearing, preferably at the seam and remove the old bearing with pliers.

11. Install the camshaft and the rest of the components by a direct reversal of the removal procedure. Refer to preceding Topic 1, of this section.



1. Handle
2. Cylinder Block
3. Camshaft Bearing
4. Remover and Installer Tool
5. Pilot

Figure 3. Removing and Installing Camshaft Bearings

TOPIC 3. VALVE LIFTERS

A. GENERAL

The valve lifters are the mushroom type and are positioned in bores on the left side of the cylinder block so that they are located above the lobes of the camshaft. The upper end of the valve lifter is machined to accept the ball end of the push rod and the lower end is contacted by the camshaft lobe. The valve lifters ride the intake and exhaust camshaft lobes, changing the rotary motion of the camshaft to a reciprocating motion to open and close the intake and exhaust valves through the action of the push rods and rocker arms.

The valve lifters are lubricated by engine oil returning by gravity from the cylinder head to the oil pan. The camshaft lobes are lubricated by oil which is splashed or sprayed by the action of the revolving crankshaft.

B. VALVE LIFTER REMOVAL

1. Remove engine from the unit.
2. Disassemble the front of the engine and remove the timing gear cover. Refer to Section 8, FRONT END AND GEAR TRAIN.
3. Remove oil pan and oil pump. Refer to Section 10, LUBRICATION SYSTEM.
4. Remove the rocker arms, shaft and brackets assembly and push rods. Refer to Section 7, VALVES, VALVE OPERATING MECHANISM AND CYLINDER HEAD.
5. Remove the camshaft. Refer to Topic 1, of this Section.

NOTE: Before camshaft is removed, lay the cylinder block on its side so that the valve lifters will not fall out of the cylinder block when the camshaft is removed.

6. Remove the valve lifters and identify them as to their location in the cylinder block so they can be reinstalled in their original location.

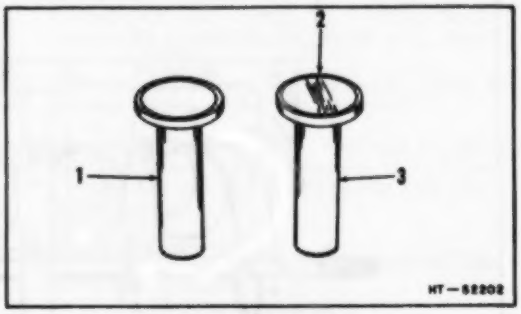
C. VALVE LIFTER INSPECTION

Very little wear takes place on the valve lifter stems or bores in the block. The specific O. D. of the valve lifter stem is .748" to .7485" and the I. D. of the bore in the cylinder block for the valve lifters is .7495" to .7505". The fit of the valve lifter in the bore of the cylinder block is .0010" to .0025". If the clearance between the valve lifter stem and the bore in the cylinder block exceeds .0035", replace the valve lifter.

Inspect the valve lifter faces which contact the camshaft lobes for roughness, scuffing, or excessive wear. These conditions can be caused by inferior quality of lubricating oil, or contaminated oil which will make the valve lifters stick in the bores and not allow them to rotate, as illustrated in Figure 1. Replace any worn valve lifters.

D. VALVE LIFTER INSTALLATION

1. Lubricate the valve lifters with clean engine oil and install them in their original location in the cylinder block.
2. Install the camshaft and the rest of the components by a direct reversal of the removal procedure. Refer to Topic 1, of this Section.



1. Good Valve Lifter
2. Worn Face
3. Worn Valve Lifter

Figure 1. Valve Lifters

SECTION 12
PISTONS, PISTON RINGS, CONNECTING RODS, AND CONNECTING ROD BEARINGS

TOPIC **TITLE**

1 PISTONS AND PISTON RINGS 12.1
    A. GENERAL
    B. PISTON, CONNECTING ROD, AND CONNECTING ROD BEARING REMOVAL
    C. REMOVAL OF CONNECTING ROD AND PISTON RINGS FROM PISTON
    D. PISTON AND PISTON RINGS INSPECTION
    E. FITTING PISTONS TO CYLINDER SLEEVES
    F. FITTING PISTON RINGS TO PISTONS
    G. PISTON RINGS INSTALLATION
    H. ASSEMBLY OF CONNECTING ROD TO PISTON
    I. PISTON, CONNECTING ROD, AND CONNECTING ROD BEARING INSTALLATION

2 CONNECTING RODS AND CONNECTING ROD BEARINGS 12.2
    A. GENERAL
    B. CONNECTING ROD AND CONNECTING ROD BEARING INSPECTION
    C. CONNECTING ROD BUSHING REPLACEMENT

TOPIC 1. PISTONS AND PISTON RINGS

A. GENERAL

The pistons are tin plated aluminum alloy and are precision machined, cam ground, and balanced. Each piston is fitted with a nickel alloy top ring insert. Three compression rings and one oil control ring are located above the piston pin. The top compression ring and the two scraper segments of the three-piece oil ring are chrome plated. Holes drilled through the walls of each piston at the oil ring groove allow excess oil collected in the groove to return to the oil pan. Piston pins are the full floating type, held in place in the piston by retainer rings.

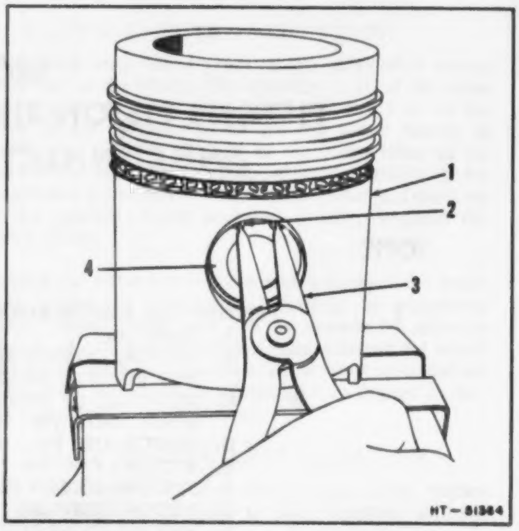
B. PISTON, CONNECTING ROD, AND CONNECTING ROD BEARING REMOVAL

Replacement of connecting rod bearings may be accomplished without removing pistons and connecting rods from the engine. If rod bearing removal only is required, follow steps 2 and 4.

1. Remove the cylinder head. Refer to Section 7, VALVES, VALVE OPERATING MECHANISM, AND CYLINDER HEAD.
2. Drain engine oil and remove oil pan, oil pump and discharge tube. Refer to Section 10, LUBRICATION SYSTEM.
3. Remove the piston ring travel ridge from the cylinder sleeve. Refer to Section 14, CYLINDER BLOCK AND CYLINDER SLEEVES.
4. Remove lock bolts securing connecting rod bearing caps. Remove bearing caps and free lower end of connecting rods from crankshaft. Remove bearing shells from bearing caps and connecting rods.
5. Carefully remove each piston and connecting rod assembly by pushing assembly out through top of cylinder sleeve.

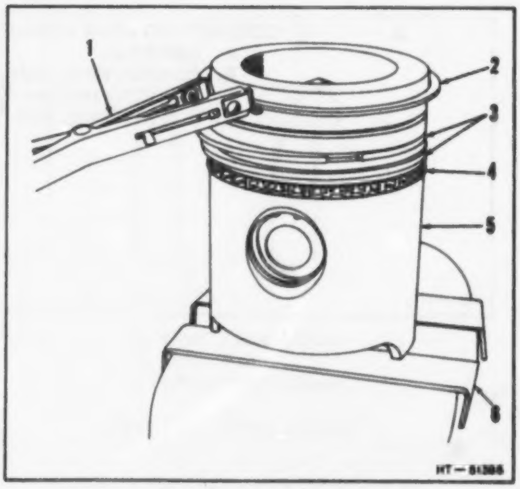
C. REMOVAL OF CONNECTING ROD AND PISTON RINGS FROM PISTON

1. Using a pair of #23 Truarc pliers, remove piston pin retainers from grooves in the piston at each end of the piston pin.
2. Remove piston rings from the piston using a ring remover and installer tool similar to the one shown in Figure 2.



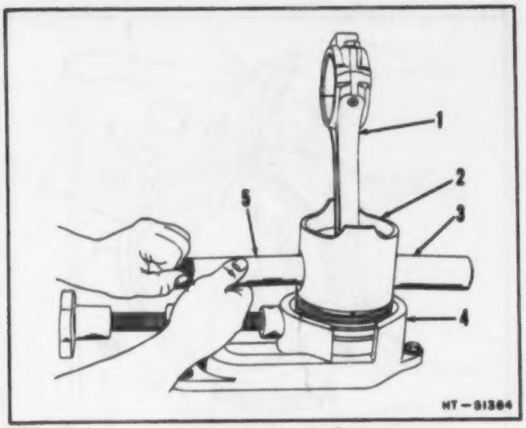
1. Piston
2. Piston Pin Retainer
3. Snap Ring Pliers
4. Piston Pin

Figure 1. Removing Piston Pin Retainer



1. Piston Ring Remover and Installer
2. Top Compression Ring (chrome plated)
3. Compression Rings
4. Oil Control Ring
5. Piston
6. Lead Protective Jaws

Figure 2. Removing Piston Ring from Piston



1. Connecting Rod
2. Piston
3. Piston Pin
4. Piston Vise
5. Piston Pin Driver

Figure 3. Removing Pin from Piston

3. Drive the piston pin from the piston, using tools similar to those shown in Figure 3. If a suitable driver tool is not available, immerse piston in 180°F. water for approximately 5 minutes. Remove pin while piston is still hot.

> NOTE: The bore in an aluminum alloy piston expands as the piston heats but provides a tight fit between pin and piston at room temperature.

D. PISTON AND PISTON RINGS INSPECTION

The normal pattern of wear on pistons will show maximum wear in the compression ring grooves. Seldom is piston replacement required because of excessive wear in the oil ring grooves or because the piston skirt or piston pin bores are excessively worn.

As gummy deposits are not always easily removed from the piston walls and ring grooves with fuel, these parts may be cleaned by using a solvent and then blowing off with dry compressed air. After cleaning, the piston skirt, piston rings, and ring grooves should be thoroughly inspected. Be sure oil drain holes in the oil ring grooves are open and clean. If the cleaning solution does not remove all carbon from the bottom of the ring grooves, break the old rings in half and use the butt ends as scrapers. Be careful to remove only carbon or foreign material; do not scrape away any metal from the side or bottom of the ring grooves.

> CAUTION: Some types of solvent contain chemicals injurious to aluminum alloy. Do not use this type of cleaning agent.

The piston skirt should be carefully examined for score marks or other indications of improper piston clearance. Inspect the inside of pistons for cracks; scored or cracked pistons should be replaced. Check pistons for wear. The skirt diameter of a new piston is 4.242" - 4.243" (measured at right angles to piston pin and at bottom of the skirt); the inside diameter of a new cylinder sleeve is 4.2495" - 4.251", giving a running clearance of .0065" to .009".

Any deviation from these measurements will indicate the amount of wear on the piston and/or the cylinder sleeve. If the piston rings are removed from the pistons, even after a short period of operation, do not reinstall the same rings; in most cases, used rings will not again seat properly. The O.D. of new piston rings have tool marks and reasonably rough surfaces which allow for a fast wear-in and seating of the rings to the cylinder walls. After a period of operation, the rings wear or lap themselves to fit perfectly with the cylinder walls and the rings "seat".

If the wear in the piston compression ring grooves does not create side clearance with new piston rings greater than .011"; if piston pin bore does not exceed 1.5026"; and if no cracks or scores are detected in piston pin bosses, on the skirt, or in the combustion chamber area, the pistons may be reused with a reasonable life expectancy of one-half to three-fourths that of new pistons.

E. FITTING PISTONS TO CYLINDER SLEEVES

Measurement of the pistons and the cylinder sleeves, and running clearances between the pistons and the cylinder sleeves, should be taken at room temperature (70°F).

> NOTE: Pistons must be fitted to their respective cylinder sleeves before the piston rings are installed to provide a running clearance of not less than .0065". Insufficient clearance will result in premature failure of pistons and/or cylinder sleeves.

1. Using an inside micrometer, measure the I.D. of the cylinder sleeve (refer to Section 14, CYLINDER BLOCK AND CYLINDER SLEEVES).
2. Using an outside micrometer, measure the O.D. of the piston skirt at a right angle to the piston pin and at the bottom of the skirt.
3. The difference between the two readings is the running clearance.

F. FITTING PISTON RINGS TO PISTONS

1. The gap between ends of piston rings should be measured before rings are installed on pistons. Insufficient end gap will cause scored rings, scored cylinder sleeves, and other damage. Check the ring gap by inserting each ring into the cylinder sleeve in which it is to be used. Use a piston to push ring squarely down in the

bore of the cylinder sleeve and far enough to be on the ring travel area. Check ring gap with a feeler gauge as shown in Figure 4. The specified ring end gaps, using standard cylinder sleeves of 4.2495" - 4.251" bore are:

Model 3400

Top Compression Ring	0.027" - 0.047"
2nd and 3rd Rings	0.015" - 0.030"
Oil Control Ring (3 pc.)	0.013" - 0.058"

Model 3500

Top Compression Ring	0.019" - 0.034"
2nd and 3rd Rings	0.015" - 0.030"
Oil Control Ring (3 pc.)	0.013" - 0.058"

> CAUTION: The top compression ring should never be filed to open the gap because the chrome plating might be loosened by the file and later distributed through the engine, causing damage or scoring of the piston and the cylinder sleeve.

2. Measure ring-to-groove clearance (top of ring to top of groove in piston) as shown in Figure 5. The specified ring to groove clearances, using a new piston and new rings, are as follows:

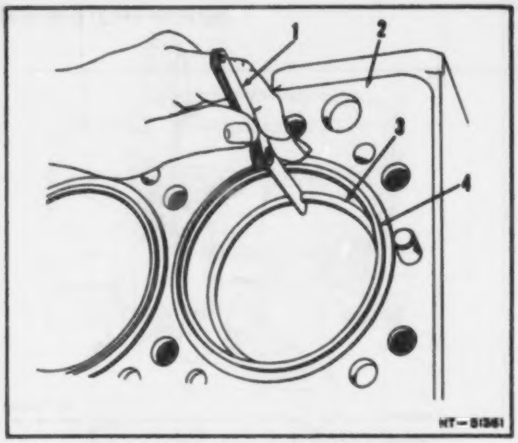
Top Compression Ring	0.0065" - 0.008"
2nd and 3rd Rings	0.003" - 0.005"
Oil Control Ring (3 pc.)	0.0025" - 0.0085"

G. PISTON RINGS INSTALLATION

After piston rings have been properly fitted, lubricate piston and rings with Series 3 engine oil. Install rings on piston (with side marked "Top" or "T" toward top of piston), using a piston ring remover and installer tool as shown in Figure 2.

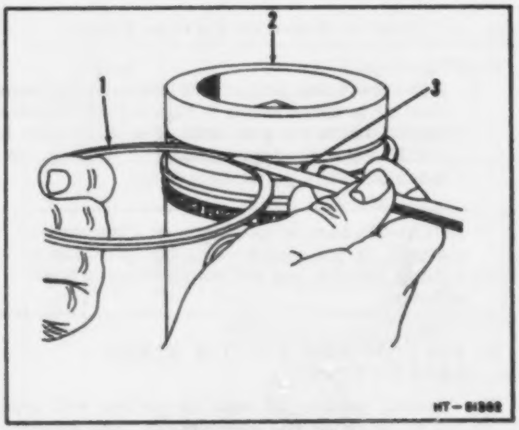
> CAUTION: When installing rings on pistons, do not spread the rings more than necessary. Whenever a connecting rod with the piston is secured in a vise, be extremely careful that the bottom of the piston skirt is not nicked. Use lead protective jaws to protect the bottom of the skirt from nicks and also to prevent nicks in the rod which will lead to piston and/or connecting rod failure.

1. Install the three piece oil control ring as follows:
   a. Place stainless steel expander spacer of three-piece ring in the bottom groove of the piston with the ends butted.
   b. Install chrome-plated steel segment on bottom side of expander spacer, with gap of segment approximately 90° beyond gap of expander spacer, making certain expander spacer is still in a butted position.



1. Feeler Gauge
2. Cylinder Block
3. Piston Ring
4. Cylinder Sleeve

Figure 4. Checking Piston Ring Gap



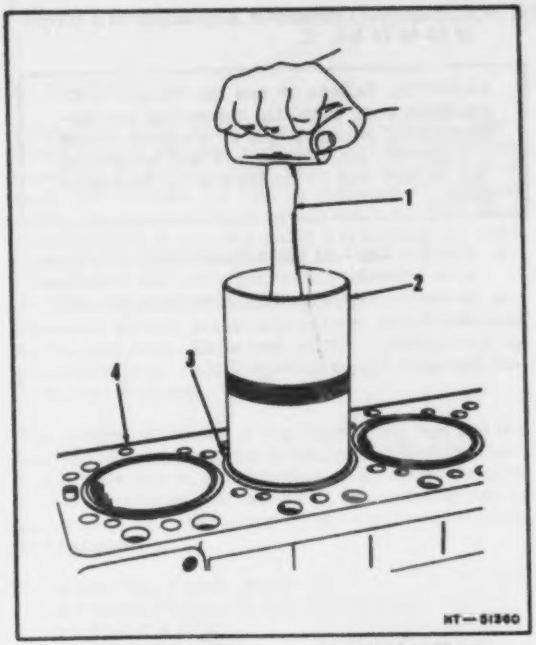
1. Compression Ring
2. Piston
3. Feeler Gauge

Figure 5. Checking Piston Ring-to-Groove Clearance

   c. Install second segment on the top side of expander spacer with segment gap approximately 90° from expander spacer gap in opposite direction from which the bottom segment has been installed.

2. Install the three compression rings. The gap of all rings must be positioned 180° apart and in line with the piston pin holes.

3. Recheck the three-piece ring assembly. Rings should be free to move in the grooves; however, a slight drag will be evident because of the side sealing action of the ring assembly. Be sure expander spacer remains in butted position.



1. Hammer Handle
2. Piston Inserter
3. Cylinder Sleeve
4. Cylinder Block

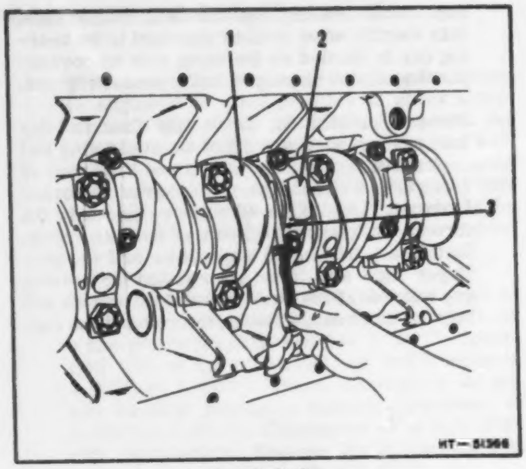
Figure 6. Installing Piston Assembly in Cylinder Sleeve

H. ASSEMBLY OF CONNECTING ROD TO PISTON

1. Before assembling connecting rod to the piston, inspect the connecting rod. Refer to Topic 2, of this Section.
2. Install one of the piston pin retainers in one end of the piston pin hole in the piston.
3. Insert upper end of connecting rod into piston.
4. Lubricate piston pin with clean oil and, with a piston pin remover and installer tool (Figure 3) tap piston pin into piston and connecting rod.
5. Install the other piston pin retainer at the opposite end of the piston pin bore.

I. PISTON, CONNECTING ROD, AND CONNECTING ROD BEARING INSTALLATION

Install each piston, with rings and connecting rods, as an assembly. The lower end of each connecting rod, as well as the connecting rod bearing caps, are numbered 1, 2, 3, etc. for identification and must be installed in the corresponding numbered cylinder with the numbered side of rod toward the camshaft side of engine.



1. Crankshaft
2. Connecting Rod
3. Feeler Gauge

Figure 7. Checking Connecting Rod Side Clearance

1. Stagger piston ring gaps evenly around piston and apply clean engine oil to pistons and rings. With a piston inserter (Figure 6) install the piston and connecting rod in the cylinder sleeve by tapping on top of piston with wooden hammer handle. If any difficulty is encountered, however slight, the piston inserter must be removed and ring set inspected for correct installation in piston grooves. Align lower end of connecting rod with crankshaft before inserting piston into cylinder.
2. Lubricate and install a bearing shell in position in connecting rod, with tang of bearing shell in the corresponding slot in connecting rod, and position rod on crankshaft journal.

> CAUTION: Make certain the backs of the bearing shells are free from dirt and grit particles.

3. Lubricate and install a bearing shell in position in the connecting rod bearing cap, with tang of bearing shell in corresponding slot in bearing

cap. Install bearing cap and shell, making certain identification number stamped in the bearing cap is located on the same side as corresponding number stamped in the connecting rod.

4. Prior to installation, thoroughly clean and dry with compressed air all of the connecting rod capscrews (lock bolts). Apply a thin coat of "Molykote G" lubricant, which can be purchased from your local Allis-Chalmers dealer, to the threads and under the heads of the capscrews. Install the lubricated capscrews and washers finger tight and force the rod and the bearing cap endwise, first to the front of the engine and then to the rear, to align the rod and the cap. Tighten the capscrews alternately to a torque of 65 to 70 lbs. ft.

CAUTION: Failure to use the "Molykote G" lubricant when installing connecting rod capscrews and failure to use an accurate torque wrench will invite capscrew and connecting rod failure due to inadequate or excessive torque.

5. Check to see that there is sufficient side clearance between connecting rods and crankshaft journals. The specified clearance is .005" - .010".

TOPIC 2. CONNECTING RODS AND CONNECTING ROD BEARINGS

A. GENERAL

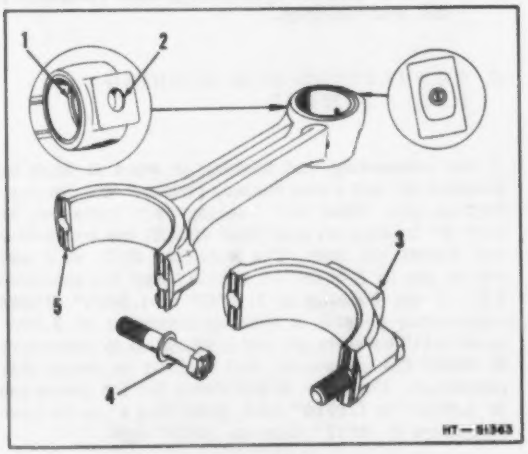
Connecting rods are made of drop-forged, heat-treated steel and are statically and electronically balanced. A funnel-shaped hole in the upper end of each rod catches oil that is splashed or sprayed within the cylinder block and allows it to flow into a radial groove in the connecting rod bushing for continuous piston pin lubrication.

The precision type connecting rod bearings are replaceable without machining and are held in position by bearing caps. Each half of the bearing shell is prevented from radial movement by a tang that extends into a recess.

The mating surfaces of the connecting rod and the bearing cap are serrated to assure side to side alignment. This type of construction gives added strength to the connecting rod assembly. The bearing cap is secured to the connecting rod by hardened washers and capscrews.

B. CONNECTING ROD AND CONNECTING ROD BEARING INSPECTION

1. Clean connecting rod so it is free from oil and other matter. Check connecting rod for cracks by the magnetic particle method. Magnetize the connecting rod and cover it with a fine magnetic powder or solution. Cracks will form a small local magnet which causes the magnetic particles in the powder or solution to gather there, marking the cracks. If any cracks are detected, the connecting rod must be replaced.



1. Oil Groove in Bushing
2. Funnel Shaped Oil Hole
3. Bearing Cap
4. Capscrew (Lock Bolt) and Washer
5. Serrations

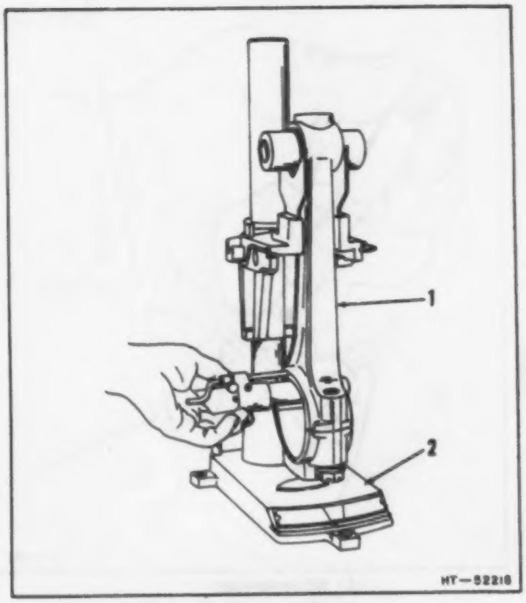
Figure 1. Connecting Rod

2. Whenever connecting rods are removed from an engine it is good practice to check alignment of the piston pin bushing end with the large bore end. Alignment can be checked with a direct reading alignment gauge similar to the one shown in Figures 2 and 3. Note that with this type alignment gauge the rod can be checked with or without the piston assembled to it.

3. Measure outside diameter of the piston pin to determine amount of wear. Specified O.D. of a new piston pin is 1.5015" to 1.5017". Specified I.D. of the connecting rod bushing is 1.5027 to 1.5032". These dimensions of pin and bushing provide a running clearance of 0.001" to 0.0017". Clearances of up to 0.003" are permissible. Replace the connecting rod bushing if clearance exceeds 0.003".

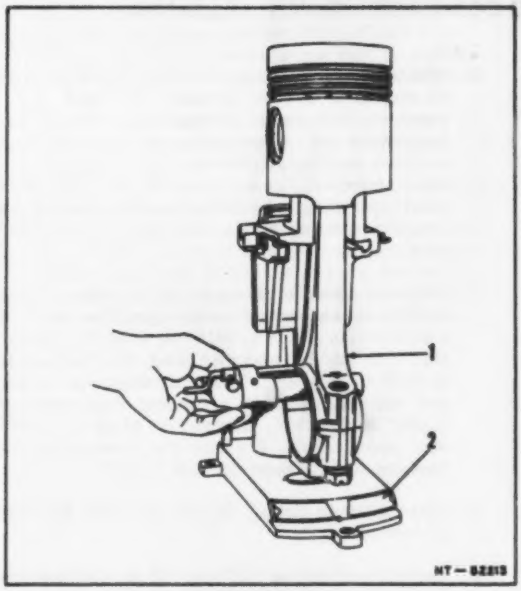
4. Make certain funnel oil hole is clean and free of foreign matter.

5. Inspect connecting rod bearing shells for scoring, chipping, corrosion, cracking, or signs of overheating; discard bearing shells if any of these conditions are apparent. The backs of bearing shells should be inspected for bright spots and discarded if any bright spots are found; this condition indicates that bearing shells have been moving in their supports.



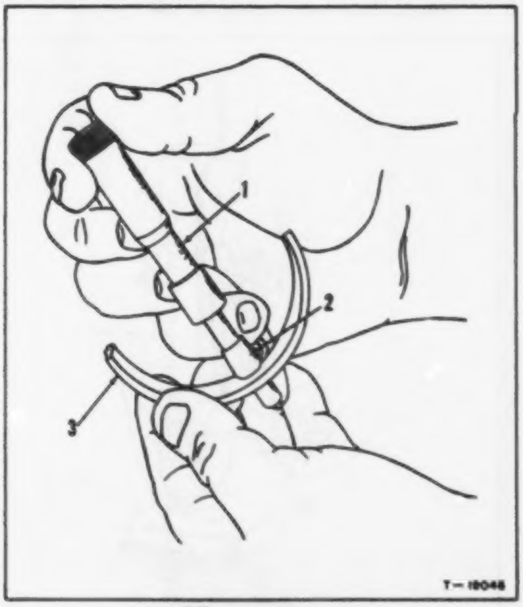
1. Connecting Rod
2. Alignment Gauge

Figure 2. Checking Connecting Rod Alignment (Rod Only)



1. Connecting Rod
2. Alignment Gauge

Figure 3. Checking Connecting Rod Alignment (With Piston)



1. Micrometer
2. Sleeve with Steel Ball
3. Bearing Shell

Figure 4. Measuring Bearing Shell Thickness

6. Inspect rod bearing shells for wear. The specified I.D. of bearing shells is 2.7495" to 2.751" installed and with connecting rod capscrews tightened to the specified torque of 65 to 70 lbs. ft. This provides a running clearance of 0.001" to 0.0035". New bearing shells must be installed when this clearance exceeds 0.009".

7. Measure connecting rod bearing shells for wear as illustrated in Figure 4. Connecting rod bearings have a specified thickness of 0.10975" to 0.11025". Shells measuring less than 0.108" at the center should be discarded and new ones installed.

In the event that the crankshaft is worn or damaged and must be ground, bearing shells .002", .010", .020", .030", and .040" undersize are available.

NOTE: Install new bearing shells if the fit is unsatisfactory. The crankshaft must turn freely after all the connecting rod cap screws have been tightened to the specified torque.

As a general recommendation, it is more practical to replace connecting rod bearings whenever they are removed from the engine after 2000 to 3000 hours of service than to reuse them. The cost of new replacement bearings will offset the gamble of reinstalling bearings with undetected fatigue, and also to prevent accelerated fatigue which may develop from a minute repositioning when reinstalling the used bearings.

C. CONNECTING ROD BUSHING REPLACEMENT

If the connecting rod bushing is worn it must be pressed out and a new bushing pressed into the connecting rod. When new bushings are installed, be sure the bushing oil hole lines up with the connecting rod funnel oil hole. The specified O.D. of a new piston pin is 1.5015" to 1.5017" and the specified I.D. of the bushing is 1.5027" to 1.5032". These dimensions provide a running clearance of 0.001" to 0.0017" between pin and bushing. It is necessary to ream the connecting rod bushing to obtain this clearance. The bore in the piston for the piston pin is 1.5014" to 1.5016" cold, providing a pin-to-bore clearance of .0001" loose to .0003" tight.

NOTE: Whenever it is necessary to replace a connecting rod bushing, it is recommended that the work be done by a reputable machine shop suitably equipped.

SECTION 13

CRANKSHAFT AND CRANKSHAFT GEAR, MAIN BEARINGS, AND MAIN BEARING CAPS

TOPIC TITLE

1 CRANKSHAFT AND CRANKSHAFT GEAR 13.1
  A. GENERAL
  B. CRANKSHAFT REMOVAL, INSPECTION, AND INSTALLATION
  C. CRANKSHAFT GEAR REMOVAL AND INSTALLATION

2 MAIN BEARINGS 13.2
  A. GENERAL
  B. MAIN BEARING REMOVAL, INSPECTION, AND INSTALLATION
  C. MAIN BEARING REPLACEMENT WITH ENGINE INSTALLED

3 MAIN BEARING CAPS 13.3
  A. GENERAL
  B. MAIN BEARING CAP REPLACEMENT

TOPIC 1. CRANKSHAFT AND CRANKSHAFT GEAR

A. GENERAL

The seven bearing, counterbalanced crankshaft is a steel drop forging, carefully heat-treated to assure utmost strength and durability. The crankshaft is balanced dynamically. End thrust of the crankshaft is taken up by thrust flanges (Figure 1) at the center main bearing. The crankshaft is drilled for pressure lubrication from the main bearings to the connecting rod bearings.

The heat-treated crankshaft gear is keyed and pressed onto the front end of the crankshaft with a .001" to .003" interference fit.

B. CRANKSHAFT REMOVAL, INSPECTION, AND INSTALLATION

1. Crankshaft Removal and Inspection.

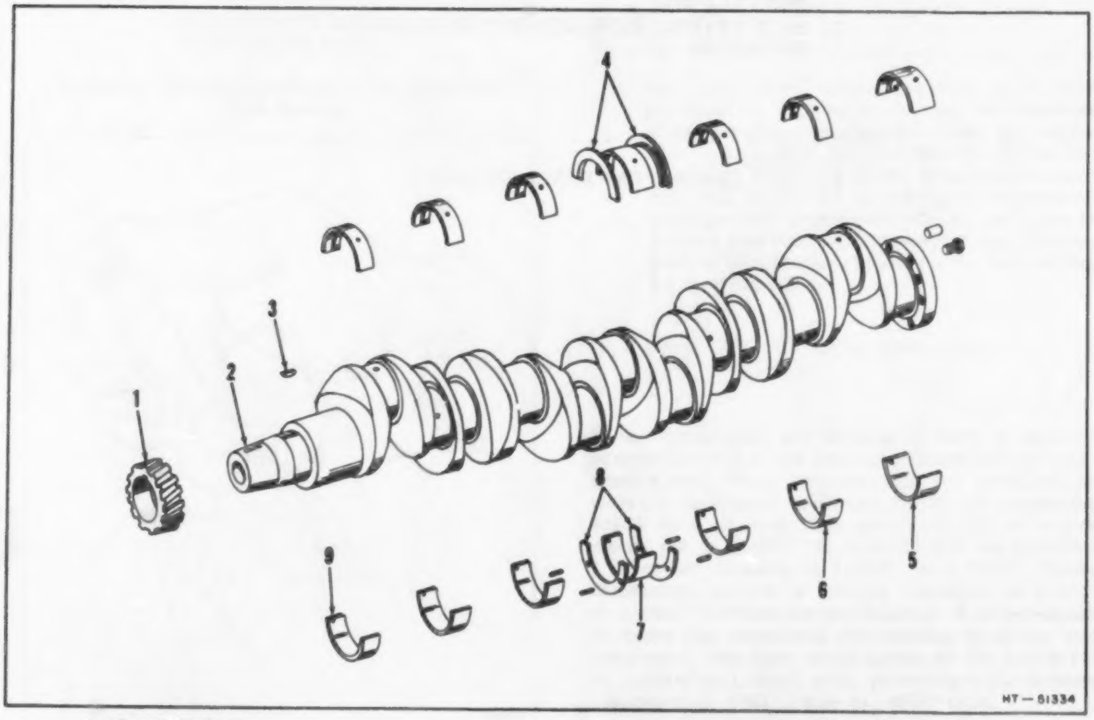
    a. Disconnect unit that is powered by the engine and remove engine from the sub-base. Drain the cooling system and drain engine lubricating oil.

    b. Disconnect wiring and remove starter. Remove flywheel and flywheel housing. Refer to Section 9, FLYWHEEL AND RING GEAR, FLYWHEEL HOUSING AND CRANKSHAFT REAR OIL SEAL.

    c. Remove oil pan, oil pump, and oil pump discharge tube. Refer to Section 10, LUBRICATION SYSTEM.

    d. Remove components on front end of engine necessary to facilitate removal of timing gear cover. Remove timing gear cover and front support plate. Refer to Section 8, FRONT END AND GEAR TRAIN.

    e. Remove connecting rod bearing caps and connecting rod bearing shells. Refer to Section 12, PISTONS, PISTON RINGS, CONNECTING RODS, AND CONNECTING ROD BEARINGS.



1. Crankshaft Gear
2. Crankshaft
3. Woodruff Key
4. Upper Thrust Flanges
5. Lower Rear Main Bearing Shell
6. Lower Intermediate Main Bearing Shell
7. Lower Center Main Bearing Shell
8. Lower Thrust Flanges
9. Lower Front Main Bearing Shell

Figure 1. Crankshaft and Main Bearings Detail

NOTE: Identify bearing shells as to their original location in the connecting rods, in the main bearing caps, and in the cylinder block in the event inspection proves they can be reused.

f. Remove main bearing caps and lower main bearing shells.

g. Remove the crankshaft.

h. Remove upper main bearing shells from the cylinder block.

i. Clean crankshaft thoroughly and inspect the journals for scoring, chipping, cracking, or signs of over-heating. If crankshaft has been over-heated (usually indicated by discolored or blue bearing journal surfaces), or is scored or excessively worn, reconditioning or replacement will be required. Examine bearing journals for cracks if over-heating has occurred.

j. Measure the crankshaft main bearing and connecting rod journals at several places on their diameter to check for roundness. The specified diameter of main bearing journals is 3.247" to 3.248"; connecting rod journals is 2.7475" to 2.7485". The only recommended method of reconditioning the crankshaft is regrinding, as required to accommodate undersize bearings. Chrome plating or metallizing the bearing journals is not recommended.

CAUTION: When regrinding a crankshaft in the field it is important that the original journal fillet radii be maintained and not decreased. Decreasing these fillet radii will weaken the crankshaft to the extent that breakage can be expected.

All main and connecting rod bearing journal surfaces of the crankshaft are hardened to a minimum depth of approximately .060". If regrinding of crankshaft journals becomes necessary, the work should be done by a reputable machine shop that has suitable equipment to handle precision work of this type. Main bearing shells .002" .010", .020", .030", and .040" undersize are available. If crankshaft is ground, the diameter of main bearing journals should be reduced in steps of .002" .010", .020", .030", or .040" below 3.247" to 3.248" to fit the undersize main bearing shells.

If out-of-round or taper of journals exceeds .002", crankshaft must be reground to a standard undersize or replaced.

k. Blow out all oil passages in crankshaft with dry compressed air.

2. Crankshaft Installation.

a. Install the upper halves of main bearing shells in position with tang of bearing shell in slot in bearing seats of the cylinder block.

CAUTION: Make certain the backs of bearing shells are free from dirt and grit particles.

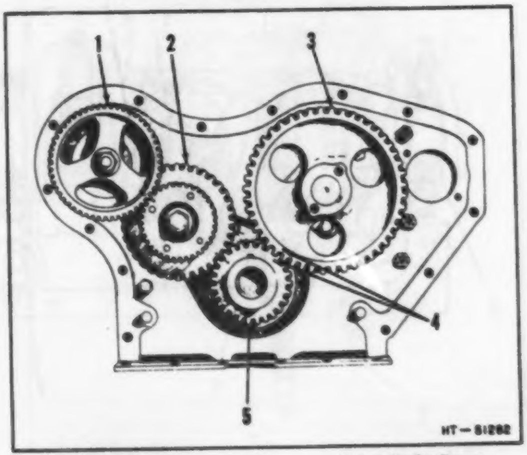
b. Lubricate all crankshaft main bearing journals with engine oil; lower the crankshaft into position in the cylinder block with flywheel flange end of crankshaft toward the rear.

CAUTION: Make certain that timing mark on crankshaft gear is aligned with timing mark on camshaft gear, when crankshaft is installed, (Figure 2).

c. Place the lower halves of the main bearing shells in position in the main bearing caps.

CAUTION: Make certain the backs of the bearing shells are free from dirt and grit particles.

d. The bearing caps are numbered 1, 2, 3, etc. Figure 3, indicating their respective positions. Before installing center main bearing cap, insert upper thrust flanges (flanges without dowel pin holes) with oil grooves of thrust flanges located next to cheeks of the crankshaft. Position lower thrust flanges on dowel pins, with the oil grooves in the thrust flanges to the outside of the bearing cap (Figures 4 and 5).



1. Fuel Injection Pump Drive Gear
2. Idler Gear
3. Camshaft Gear
4. Timing Marks
5. Crankshaft Gear

Figure 2. Crankshaft Gear and Camshaft Gear Timing Marks Aligned

e. Install main bearing caps with numbers facing camshaft side of the engine and corresponding to number stamped on lower edge of cylinder block as shown in Figure 3. Install the main bearing cap attaching lock bolts snugly. Force crankshaft in both directions to align the bearing caps with the upper portion of the main bearing bores.

f. Using a torque indicating wrench, tighten the main bearing cap lock bolts to a torque of 170 to 190 lbs. ft.

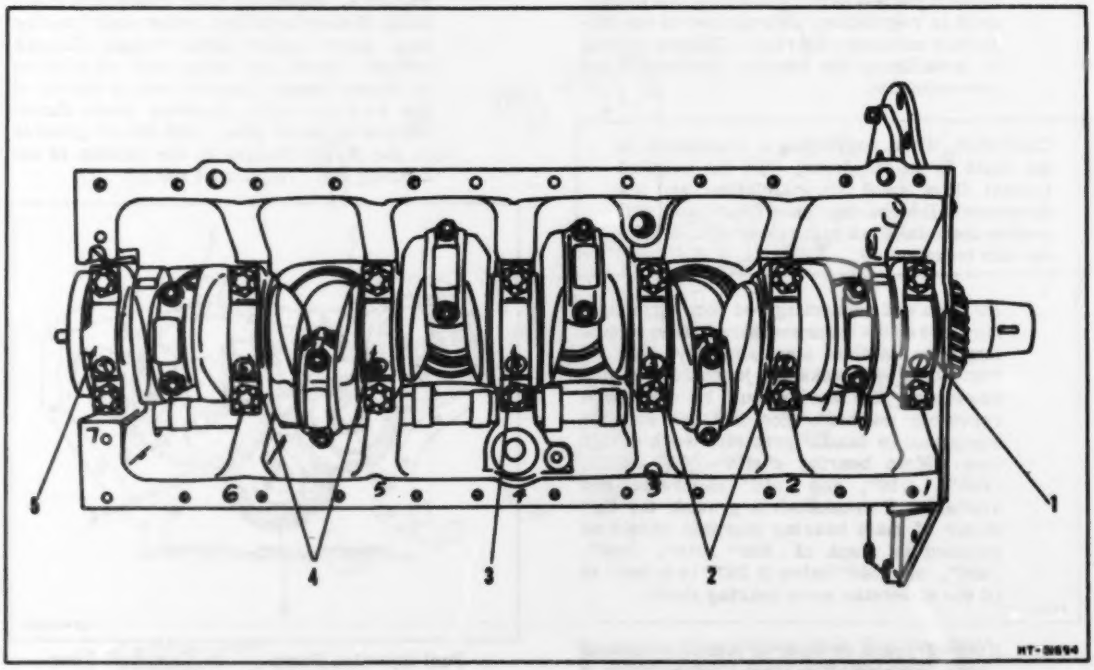
> CAUTION: Do not overtighten main bearing lock bolts. If these lock bolts are overtightened, bearing caps may be distorted, causing bearings to be drawn tight against the crankshaft and premature failure will result. The crankshaft should turn freely after all capscrews are properly torqued. Never file or shim a bearing cap to make the bearing shell fit; install new bearing shells if fit on the crankshaft is unsatisfactory.

g. Check end play of the crankshaft using a dial indicator as illustrated in Figure 6. Tap crankshaft with a soft headed hammer in one direction to take up slack or end play. After dial indicator is set in place, force crankshaft with a pry bar in opposite direction to obtain end play reading. The specified end play is .007" to .013" and must not exceed .021". The end play is controlled by thrust flanges at the center main bearing. If end play is not within the specified range, replace thrust flanges. Thrust flanges are available in standard thickness (.126" to .127") and .005", .010", and .015" oversize.

h. Install connecting rod bearing caps and shells, and check side clearance between connecting rods and crankshaft journals. Refer to Section 12, PISTONS, PISTON RINGS, CONNECTING RODS AND CONNECTING ROD BEARINGS.

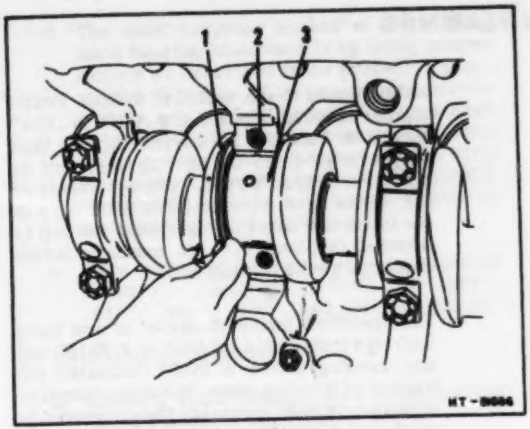
i. Install the oil pump and complete the rest of the installation by a direct reversal of the removal procedure in this Topic.

j. Fill the cooling system and fill the engine crankcase to proper level with the specified oil.



1. Front Main Bearing Cap
2. Intermediate Main Bearing Caps
3. Center Main Bearing Cap
4. Intermediate Main Bearing Caps
5. Rear Main Bearing Cap

Figure 3. Main Bearing Caps Location

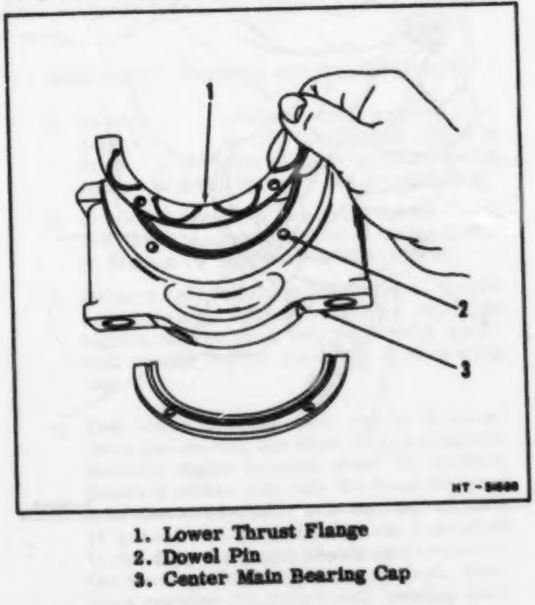


1. **Upper Thrust Flange**
2. **Center Main Bearing Upper Shell**
3. **Crankshaft Main Bearing Journal**

Figure 4. Installing Upper Thrust Flange

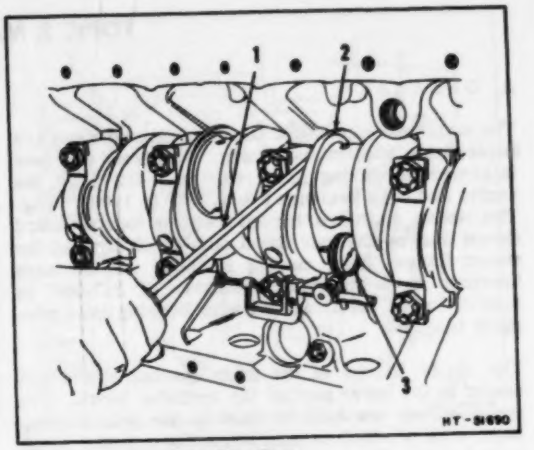
C. CRANKSHAFT GEAR REMOVAL AND INSTALLATION

The crankshaft gear may be removed from the crankshaft by the use of tools similar to those shown in Figure 7. The gear may be removed either with the crankshaft installed in the engine or after the crankshaft has been removed.



1. **Lower Thrust Flange**
2. **Dowel Pin**
3. **Center Main Bearing Cap**

Figure 5. Installing Lower Thrust Flange

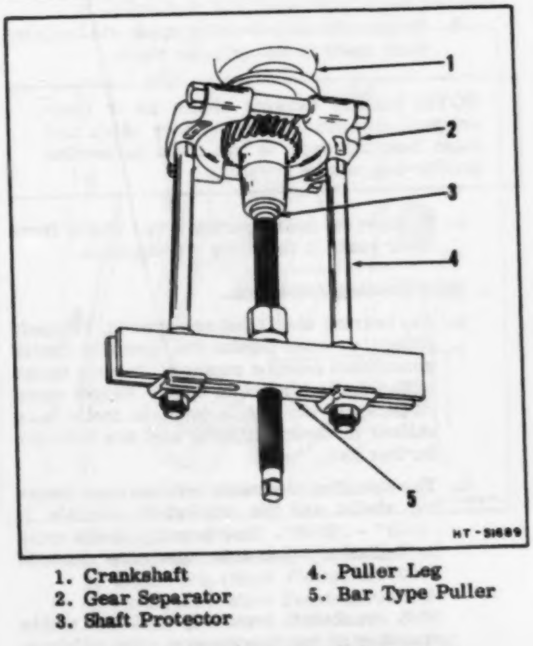


1. **Pry Bar**
2. **Crankshaft**
3. **Dial Indicator**

Figure 6. Measuring End Play of Crankshaft

To install crankshaft gear on crankshaft, install woodruff key, in crankshaft. Heat gear in oil to a temperature of approximately 300°F. Coat crankshaft, at gear location, with a mixture of white lead and oil; drive or press gear onto crankshaft. Use asbestos gloves when handling the heated gear.

CAUTION: If crankshaft is installed in engine, make certain that timing mark on crankshaft gear is aligned with timing mark on camshaft gear when crankshaft gear is installed, Figure 2.



1. **Crankshaft**
2. **Gear Separator**
3. **Shaft Protector**
4. **Puller Leg**
5. **Bar Type Puller**

Figure 7. Removing Crankshaft Gear

TOPIC 2. MAIN BEARINGS

A. GENERAL

The main bearings are of the precision type and are replaceable without machining. The front and four intermediate bearings are 1.432" to 1.442" long; the center and rear bearings are 1.682" to 1.692" long. The center main bearing kit includes four standard thrust flanges and four dowel pins which prevent the thrust flanges from moving radially. All the main bearings have an inside diameter of 3.2499" to 3.2516" when installed and with bearing caps properly torqued.

The upper halves of the main bearing shells are seated in the lower part of the cylinder block. The lower halves are held in place by the main bearing caps, each of which is attached to the cylinder block by lock bolts. The bearing shells are prevented from radial movement by a tang on the bearing shell which locates in a slot in the bearing seat of the cylinder block and the bearing cap. The upper bearing shells have two oil holes in them and must be installed in the cylinder block; however, the lower bearing shells do not have any oil holes and are installed in the bearing caps.

B. MAIN BEARING REMOVAL, INSPECTION, AND INSTALLATION

1. Main Bearing Removal.

   a. Remove the crankshaft (refer to Topic 1 in this Section).

   b. Remove the main bearing upper shells from their seats in the cylinder block.

NOTE: Identify bearing shells as to their original location in the cylinder block and main bearing caps in the event inspection proves they can be reused.

   c. Remove the main bearing lower shells from their seats in the main bearing caps.

2. Main Bearing Inspection.

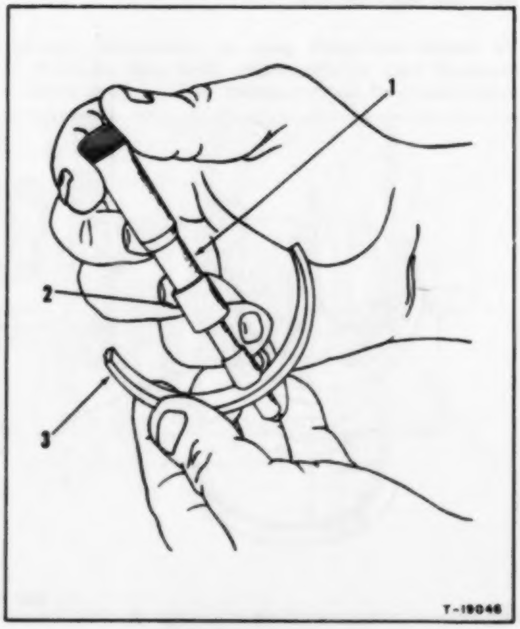
   a. Any bearing shells that are scored, chipped, pitted, or worn beyond the specified limits given below must be replaced. Inspect backs of the shells for bright spots. Bright spots on backs of the shells indicate shells have shifted in their supports and are unfit for further use.

   b. The specified clearance between main bearing shells and the crankshaft journals is .0019" - .0046". New bearing shells must be installed when this clearance exceeds .009".

   With crankshaft removed, measure inside diameter of the bearing at a point 90° from the parting line, with bearing cap installed and tightened to the specified torque. Bearing shells when in place are .002" to .004" larger in diameter at the parting line than they are 90° from the parting line, and do not form a true circle. The two halves of the shells have a crush fit in their bore in the block and must be tight when the cap is secured in place. Do not measure inside diameter at the parting line.

   The specified inside diameter of new main bearings installed is 3.2499" to 3.2516" and any reading above 3.2516" indicates the amount of bearing wear. Measure diameter of the crankshaft journal at the corresponding bearing location and subtract this dimension from inside diameter measurement of the bearing (as determined above); the difference between these two measurements is the crankshaft-to-bearing clearance.

   c. Another method for determining amount of wear on bearing shells is by measuring each shell with a micrometer at a point 90° from the parting line as shown in Figure 1. New shells, measured as shown, are .1549" to .1554" thick. Bearing shells less than .153" thick are worn beyond the allowable limits and must be replaced.



1. Micrometer
2. Sleeve with Steel Ball
3. Bearing Shell

Figure 1. Measuring Bearing Shell Thickness

d. The most accurate method of determining main bearing clearance is by using micrometers as described in the preceding paragraphs. However, if the proper size micrometers are not available or the crankshaft is installed in the engine, bearing clearance may be measured by using a plastic strip manufactured for this purpose. The plastic strip must be used in accordance with the manufacturer's instructions.

e. Main bearings are available in standard thickness (.1549" to .1554") and .002", .010", .020", .030", and .040" undersize.

3. Main Bearing Installation.

a. Install a main bearing shell in each of the bearing seats in the cylinder block.

CAUTION: Make certain the backs of the bearing shells are free from dirt and grit particles.

b. Lubricate all crankshaft main bearing journals, install crankshaft and main bearing caps, check crankshaft end play, and reassemble engine (refer to Topic 1 in this Section).

C. MAIN BEARING REPLACEMENT WITH ENGINE INSTALLED

It is unwise to replace main bearings without removing the engine and taking it into a clean shop where disassembly and inspection can be effected properly; however, when removal of the engine is impractical or in emergency cases, the following procedure may be used.

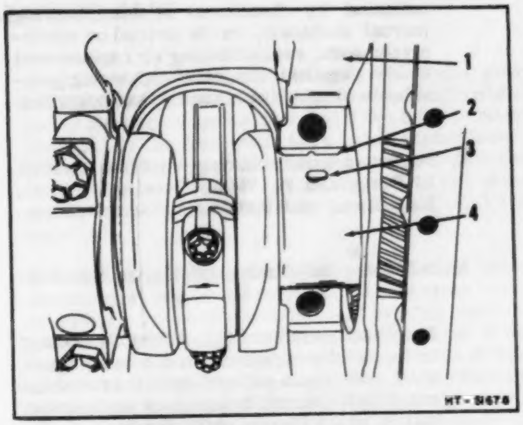
1. Main Bearing Removal with Engine Installed.

a. Remove [illegible]jection nozzle holders from engine [illegible] FUEL SYSTEM, Topic in Secti[illegible] 1) in order to relieve compression and allow free turning of the crankshaft.

b. Drain oil from oil pan and remove the oil pan, oil pump, and associated tubing (refer to Section 10 LUBRICATION SYSTEM).

c. Remove only one main bearing cap, install new bearing, reinstall bearing cap, and tighten cap retaining lock bolts to the specified torque before removing next bearing cap.

d. The lower bearing shell can be removed from the bearing cap after cap is removed. Remove upper bearing shell as follows: Insert a cotter pin with the head flattened into the crankshaft main bearing oil hole (Figures 2 and 3), then rotate the crankshaft in the direction that will remove the end of the bearing shell with the tang first. Continue rotating crankshaft until bearing shell has been pushed out.

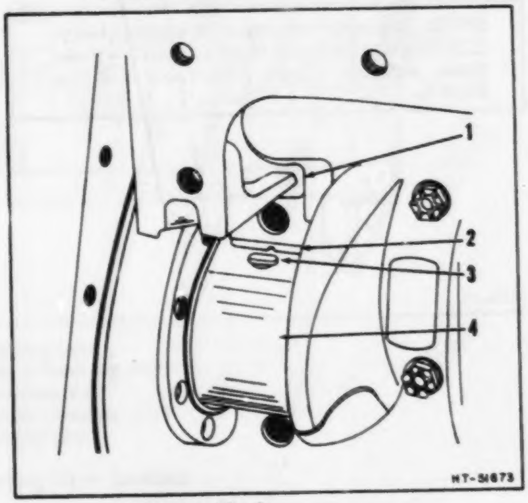


1. Cylinder Block
2. Front Main Bearing Upper Shell
3. Cotter Pin (Head Flattened)
4. Crankshaft Main Bearing Journal

Figure 2. Removing Front Main Bearing Upper Shell

NOTE: The crankshaft main bearing oil holes are drilled at an angle in the front, center, and intermediate journals, and the rear main bearing oil hole is drilled perpendicular to the journal.

e. Inspect the crankshaft journals for scoring, chipping, cracking, or signs of overheating. If crankshaft has been overheated (usually



1. Cylinder Block
2. Rear Main Bearing Upper Shell
3. Cotter Pin (Head Flattened)
4. Crankshaft Main Bearing Journal

Figure 3. Removing Rear Main Bearing Upper Shell

indicated by discolored or blue bearing journal surfaces), or is scored or excessively worn, reconditioning or replacement will be required. Examine the bearing journals for cracks if overheating has occurred.

f. Inspect each main bearing shell as described in Paragraph B, "Main Bearing Removal, Inspection, and Installation" in this Topic.

2. Main Bearing Installation with Engine Installed.

a. Install all main bearings, except the center main, as follows: Lubricate a bearing upper shell with clean oil and roll it around the crankshaft journal in the opposite direction that it was removed until the tang on the bearing shell is in position in the slot in the cylinder block.

CAUTION: Make certain the backs of the bearing shells are free from dirt and grit particles.

b. Install a bearing lower shell in position in the bearing cap. Lubricate the bearing shell and place the bearing cap in position on the cylinder block with the number facing the camshaft side. Install the cap retaining capscrews (lock bolts); tighten the capscrews evenly to the specified torque (refer to Paragraph B, Topic 1 in this Section).

NOTE: The main bearing caps are numbered 1, 2, 3, etc. indicating their respective positions, refer to Figure 3 in Topic 1 of this Section.

c. Lubricate and install the upper half of center main bearing shell. Install the upper halves of the thrust flanges (flanges without dowel pin holes) with oil grooved side of flanges toward cheeks of crankshaft. Install a bearing shell in position on the dowel pin in the center main bearing cap. Install the lower halves of the thrust flanges on the dowel pins in the center main bearing cap, Figure 5 in Topic 1 of this Section, with the oil grooved side of flanges to the outside of bearing cap. Lubricate and place bearing cap in position on cylinder block with the number facing the camshaft side. Install cap retaining capscrews.

d. After all bearing shells have been installed, retighten main bearing capscrews (lock bolts) using a torque indicating wrench. Tighten the capscrews evenly to the specified torque (refer to Paragraph B, Topic 1 in this Section).

CAUTION: Do not overtighten main bearing capscrews (lock bolts). If these capscrews are overtorqued, bearing caps will be distorted, causing bearing to be drawn tight against the crankshaft journals and premature failure will result. The crankshaft should turn freely after all capscrews are tightened to the specified torque.

e. Check crankshaft end play (refer to Topic 1 in this Section).

f. Install oil pump and discharge tube (refer to Section 10, LUBRICATION SYSTEM). Install oil pan. Fill engine crankcase to the proper level with the specified oil.

g. Install fuel injection nozzle holders (refer to FUEL SYSTEM Topic in Section 1).

TOPIC 3. MAIN BEARING CAPS

A. GENERAL

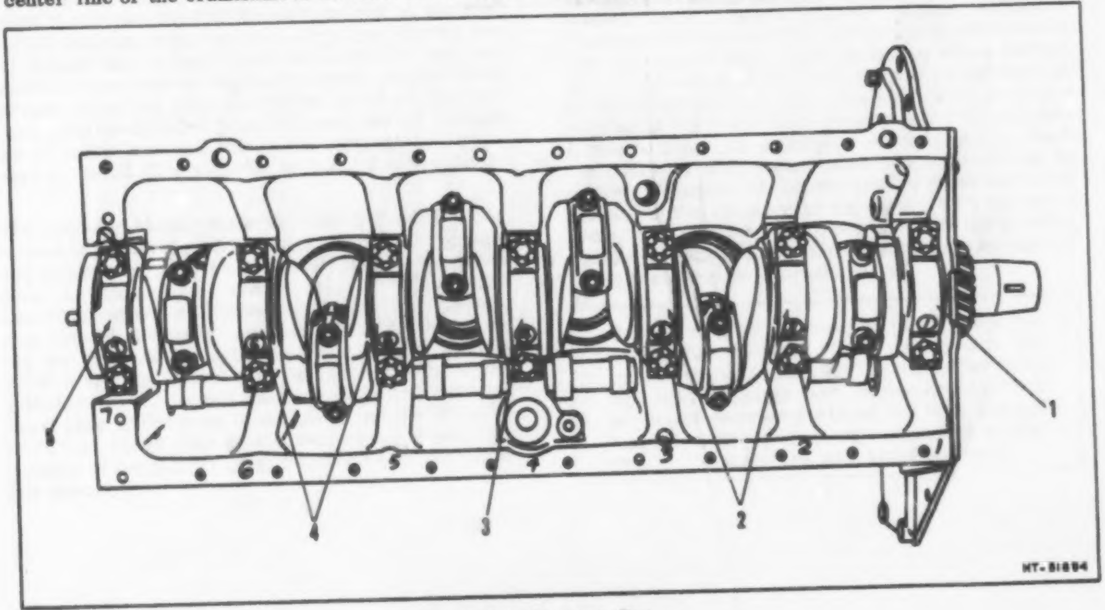
Replacement caps for front, intermediate, and rear bearing locations are machine finished except for the bore which is semi-finished. The replacement center cap is machine finished except for the bore and the thrust faces.

Main bearing caps are not interchangeable, and if replacement becomes necessary, new caps must be machined in place. To maintain correct alignment and size in the main bearing bore in the block, caps must be installed to the specified torque before machining. Replacement of main bearing caps is a machine shop job.

B. MAIN BEARING CAP REPLACEMENT

When it is necessary to do any machining to the main bearing bore in the block, it is important that the center line of the crankshaft is not altered from its original center line, especially at the timing gear end. Raising the bore .003" to .004" at the flywheel end of the engine can be tolerated if the bore is made straight and the front main bore is not repositioned. When installing a replacement cap, make certain the casting or part number on the cap is in the same relative position as the number on the old cap when installed.

If a main bearing burns out with enough heat to cause distortion at one or more of the main bearing bores or saddles, generally the block and bearing caps will pull in at their joint causing an oblong bore. If the flat areas, where the cap contacts the block around the main bearing attaching capscrews, have distorted so they are no longer flat and straight, the area will have to be hand filed and fitted to the replacement bearing cap so that when the new cap is installed it will not be distorted from being pulled down on an out-of-square surface. A thin coat of Prussian Blue can be used on the new cap to detect any out-of-squareness at this point.



1. Front Main Bearing Cap
2. Intermediate Main Bearing Caps
3. Center Main Bearing Cap
4. Intermediate Main Bearing Caps
5. Rear Main Bearing Cap

Figure 1. Main Bearing Caps Location

SECTION 14

CYLINDER BLOCK AND CYLINDER SLEEVES

TOPIC	TITLE	
1	CYLINDER BLOCK . . . . A. GENERAL B. CYLINDER BLOCK CLEANING AND INSPECTION	14.1
2	CYLINDER SLEEVES . . . . A. CYLINDER SLEEVE INSPECTION AND REMOVAL B. CYLINDER SLEEVE INSTALLATION C. CYLINDER SLEEVE RESEATING D. CYLINDER SLEEVE RESEATING TOOL	14.2

TOPIC 1. CYLINDER BLOCK

A. GENERAL

The cylinder block, which is the main structural part of the engine, is a one-piece casting made of alloy cast iron. Transverse members, cast integral, provide rigidity and strength, assuring accurate alignment of the crankshaft bearings and cylinder sleeves. The cylinder block is cored to receive removable wet-type cylinder sleeves. The cylinder sleeves are completely surrounded by water jackets which extend the full length of the cylinder walls for maximum cooling.

The cylinder block contains a main oil gallery which extends lengthwise through the cylinder block. Oil passages direct the oil from the main oil gallery to the main bearings and from the main bearings to the camshaft bearings. A vertical oil passage from the bottom of the cylinder block extends to a horizontal passage which runs to the rear of the block, directs the oil to the oil filters. The oil from the filters then flows thru a passage into the main gallery. A vertical drilled passage from the main oil gallery directs the oil through the cylinder head to the rocker arm assembly. Whenever an engine oil cooler (Model 3500) is used, a gallery plug is installed in the vertical oil passage in the cylinder block to direct the oil through the oil cooler before it enters the horizontal oil passage to the oil filters. Refer to Topic 4 of Section 2.

The cylinder block, when ordered for service, is furnished with camshaft bearings, main bearing caps and capscrews, and the necessary plugs. Six dowel pins, a rebuilt engine name plate, four name plate attaching screws, a distributor hole plug and a gallery plug (Model 3500 only) are also furnished in a cloth bag and wired to the cylinder block. Install the two 7/16" x 3/4" lg. dowel pins in the top deck of the cylinder block. Install the two 1/2" x 1-3/8" lg. dowel pins in the front of the block and the two 1/2" x 7/8" lg. dowel pins in the rear of the block. For location of the gallery plug, refer to Figure 1, Topic 4 of Section 2.

The removable wet-type cylinder sleeves are made of alloyed cast iron. Three packing rings, fitted into grooves in the lower outside circumference of the sleeve prevent water leakage into the oil pan. The sleeve is retained at the top by a flange which fits into a machined recess in the cylinder block. The cylinder head gasket is compressed between this flange and the cylinder head, holding the sleeve in place and serving as a coolant and pressure seal at the upper end of the sleeve.

B. CYLINDER BLOCK CLEANING AND INSPECTION

Whenever the engine is being overhauled, the block should be thoroughly inspected for any conditions that would render it unfit for further use. Such inspection must be made after all the parts have been removed and it has been thoroughly cleaned with live steam, or a suitable solvent, and dried with compressed air.

All the oil passages in the cylinder block must be cleaned before assembling the engine. Effective cleaning of these passages can be accomplished only with the use of high steam pressure with a solvent used in the water to dissolve the sludge and foreign material that has collected. Remove the oil pressure regulating valve and the various plugs of the oil galleries to clean the passages. After cleaning, flush the passages with clean water (under pressure) to remove all traces of the solvent. To clean the water jacket of the cylinder block, apply high pressure steam and water to the block and turn the block in various positions while this is being done so that the loose scale will be washed out.

> CAUTION: Note the location of the plugs removed for cleaning of the passages in the cylinder block and be sure the regulating valve and all the plugs are reinstalled in their proper places after the block has been cleaned and dried. The plugs must be installed so that they do not interfere with attached parts.

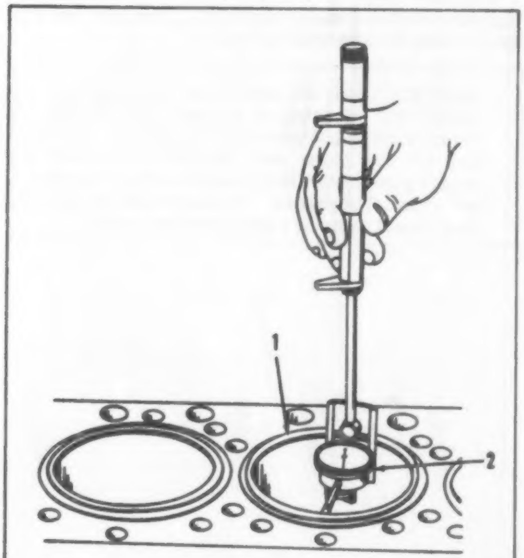
TOPIC 2. CYLINDER SLEEVES

A. CYLINDER SLEEVE INSPECTION AND REMOVAL

The cylinder sleeves may be removed and replaced while the engine is installed in the unit by removing the cylinder head, oil pan, oil pump and associated tubing, and the piston and connecting rod assemblies.

> NOTE: Removal of the cylinder sleeves while the engine is installed is only recommended in emergencies or when it is impractical to remove the engine from the unit.

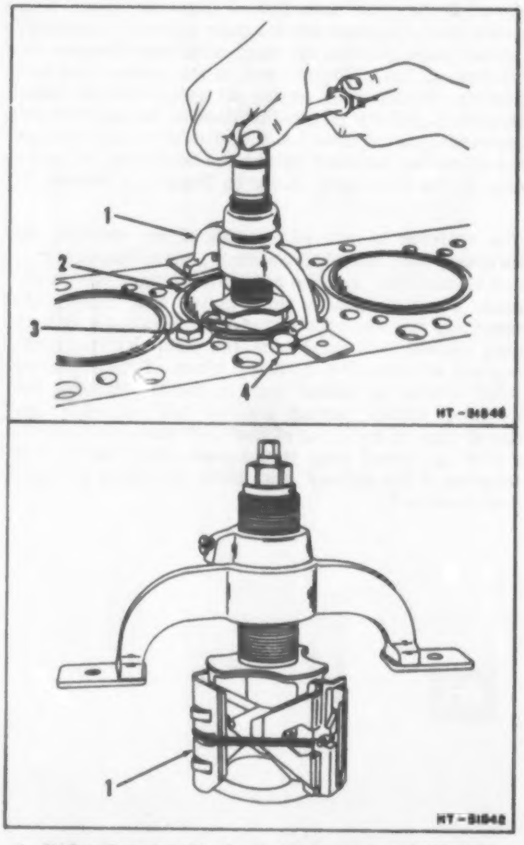
1. Check cylinder sleeves for roundness by means of a gauge similar to the one shown in Figure 1. Using an inside micrometer, measure cylinder sleeve for taper and wear. The specified inside diameter of a cylinder sleeve is 4.2495" to 4.251". When measuring cylinder sleeves with an inside micrometer, first measure in a position parallel to crankshaft and then at right angles to crankshaft. These measurements should be taken at several locations within the area of piston ring travel. The normal pattern of wear in cylinder sleeves will show maximum wear at the top three-fourths of ring travel. If maximum sleeve wear at top of ring travel does not exceed .0015" out-of-round, .0015" taper, .008" total wear, and if no deterioration of the flange has occurred to decrease the specified protrusion (standout), the sleeves may be reinstalled with a life expectancy of approximately one-half to three-fourths of new sleeves. The sleeves must be free of cracks, scores, and other physical defects.



1. Cylinder Sleeve
2. Cylinder Diameter Checking Gauge

Figure 1. Checking Cylinder Sleeve for Roundness

2. If the cylinder sleeves are to be reused, it is important that the ridge above the ring travel is removed with a hone or a ridge removing tool similar to the one shown in Figure 2, and also that the glaze in ring travel area is removed with a cylinder hone or glaze breaker tool. Hone the sleeve to a cross hatch pattern at angles of 22° to 32° to a plane perpendicular to the bore axis. The cross hatch should be nearly uniform in both directions. Do not over-hone; stop when glazed area is removed. Thoroughly clean the sleeve with warm water and common laundry detergent and scrub the bore with a stiff bristle



1. Ridge Reamer Tool
2. Cylinder Sleeve
3. Capscrew and Washer
4. Capscrew

Figure 2. Removing Ring Travel Ridge from Cylinder Sleeve

like brush. Dry the sleeve with compressed air and inspect the bore to see that it is not oversize. After cleaning protect the bore of the sleeve with a thin coating of engine lubricating oil.

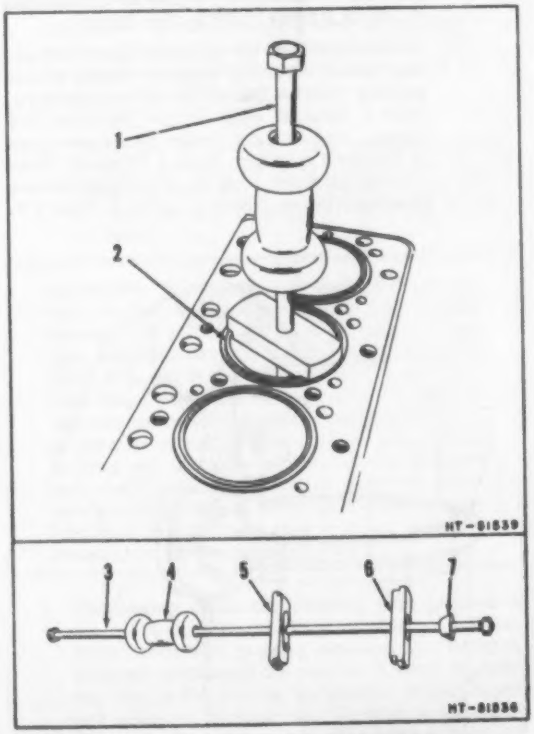
> **CAUTION: If the cylinder sleeve was honed while installed in the cylinder block, clean the block thoroughly to make certain that all abrasive material is removed.**

3. Remove cylinder sleeves using removal tool as shown in Figure 3 and 4.

4. Remove all dirt, carbon, and oil from cylinder sleeves and from the machined recess and bore in cylinder block. Replace sleeves if scored or cracked.

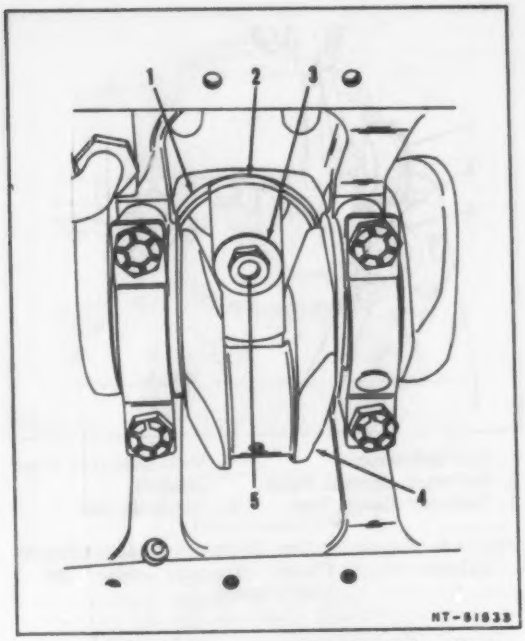
B. CYLINDER SLEEVE INSTALLATION

1. Thoroughly clean cylinder sleeve and the bore in cylinder block. Make certain bottom surface of flange on cylinder sleeve and the counterbore in cylinder block are clean and free from nicks or burrs. Before installing packing rings on sleeve, insert sleeve into bore of cylinder block to make sure sleeve can be pushed down into place and turned in the bore by hand pressure. If the sleeve cannot be inserted and turned in the above manner, more cleaning is necessary.



1. Cylinder Sleeve Removal Tool
2. Cylinder Sleeve
3. Puller Rod
4. Slide Hammer
5. Top Shoe Assembly
6. Puller Shoe
7. Shoe Centering Cone

Figure 3. Removing Cylinder Sleeve - Top View



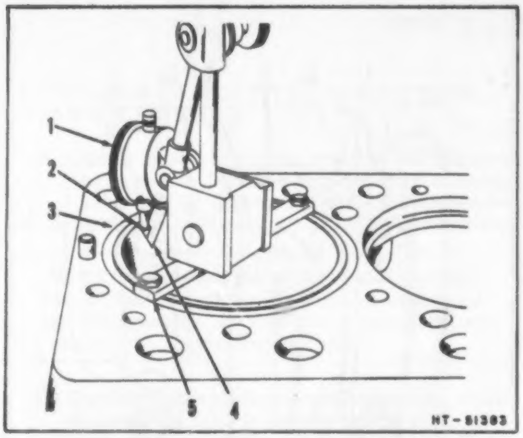
1. Cylinder Sleeve
2. Cylinder Sleeve Puller Shoe
3. Shoe Centering Cone
4. Crankshaft
5. Puller Rod and Nut

Figure 4. Removing Cylinder Sleeve - Bottom View

2. Check the out-of-square relationship of the cylinder sleeve counterbore to the center line of the cylinder using a special sleeve tool with an attached dial indicator as shown in Figure 5. Rotate the sleeve with the contact point of the dial indicator, contacting the bottom of the counterbore as shown in Figure 5. Total indicator reading should not exceed .002". If the total dial indicator reading exceeds the specified limit, reworking of the counterbore is necessary (refer to CYLINDER SLEEVE RESEATING in this Topic). The special sleeve tool, shown in Figure 5, is made from a new cylinder sleeve. The sleeve is machined as follows to assure proper relationship between the lower surface of the sleeve flange and the sleeve center line:

   a. Place the flange end of a new sleeve in the chuck of a lathe.

   b. True the center line of the sleeve as closely as possible to the lathe center by using dial indicators at each end of the sleeve.

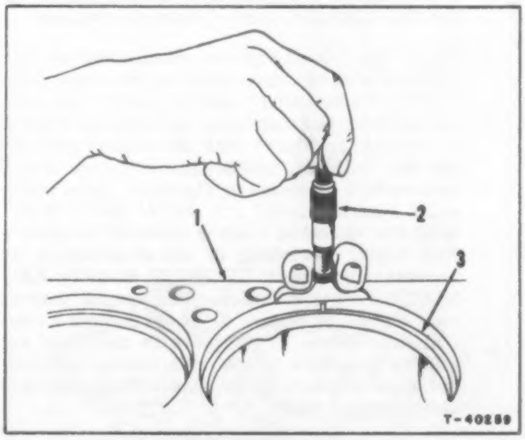


1. Dial Indicator
2. Indicator Contact Point
3. Cylinder Sleeve Tool
4. V-Section (Cut from Sleeve)
5. Mounting Bar

Figure 5. Measuring Out-Of-Square Relationship of Cylinder Sleeve Counterbore with Center Line of Cylinder

c. If necessary, machine the bottom surface of the sleeve flange to make it as true as possible to a 90° angle with the sleeve center line.

d. Refer to Figure 5 and cut a V-section out of the sleeve to allow the dial indicator to contact the sleeve counterbore in the cylinder block. Drill and tap two holes in the sleeve and attach a strap or bar as shown.



1. Cylinder Block
2. Depth Micrometer
3. Bottom of Counterbore

Figure 6. Measuring Depth of Cylinder Sleeve Counterbore

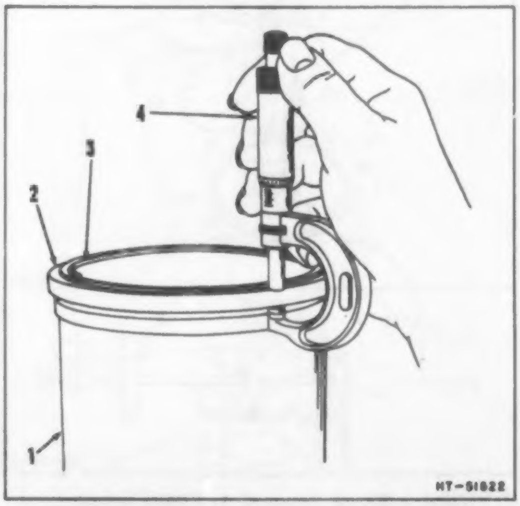
3. The protrusion (standout) of the cylinder sleeve flange above the top flat surface of the cylinder block is very important. The specified standout is .002" - .005". Measure cylinder sleeve standout as follows:

   a. Using a depth micrometer, as shown in Figure 6 measure depth of cylinder sleeve counterbore in the cylinder block (measure at two or more locations). The specified depth is .315" to .3165".

   b. Using a micrometer, as shown in Figure 7, measure width of cylinder sleeve flange (measure at two or more locations). The specified width is .3185" to .320".

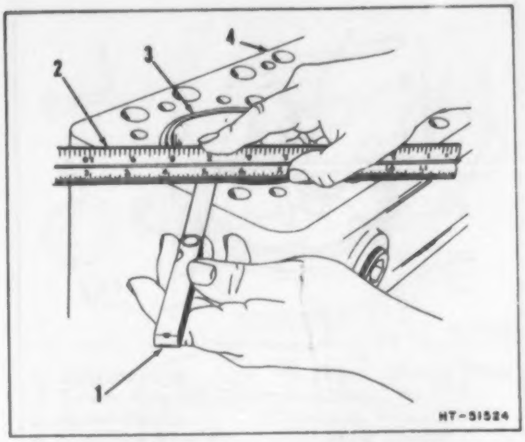
   c. Subtract counterbore depth from width of cylinder sleeve flange. The result is the cylinder sleeve standout. If the standout is not within the specified .002" - .005", install a cylinder sleeve shim of the proper thickness in the sleeve counterbore to bring the standout within the specified limits. Cylinder sleeve shims are available in .005", .010", .015" and .020" thickness. If shimming will not correct the cylinder sleeve standout, reworking of the counterbore will be necessary (refer to CYLINDER SLEEVE RESEATING in this Topic).

   d. To double check the cylinder sleeve standout, insert sleeve in cylinder block, firmly seating sleeve flange in the counterbore. Hold a straight edge across top of sleeve flange, and using a feeler gauge as shown in Figure 8 measure sleeve standout. Make certain straight edge is on cylinder sleeve flange and not on firewall, refer to Figure 7.



1. Cylinder Sleeve
2. Cylinder Sleeve Flange
3. Fire Wall
4. Micrometer

Figure 7. Measuring Width of Cylinder Sleeve Flange



1. Feeler Gauge
2. Straight Edge
3. Cylinder Sleeve
4. Cylinder Block

Figure 8. Measuring Cylinder Sleeve Flange Height (Standout) above Cylinder Block

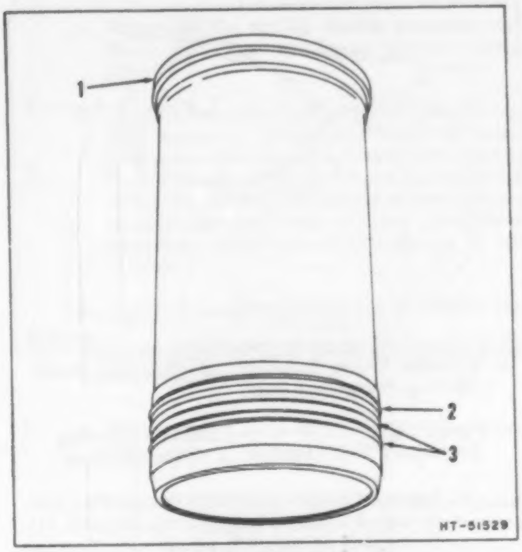
CAUTION: Do not attempt to measure cylinder sleeve standout in this manner with a shim installed in counterbore, rough edges or burrs on shim may give a false reading.

4. Two types of packing rings are used on each cylinder sleeve, silicone rubber, and Buna N rubber. They are identified by their color. Silicone packing rings are red; Buna N rings are black.

CAUTION: Silicone rubber packing rings are very tender, having less than half the tensile strength of the black Buna N packing rings. Use extreme care in handling and installing them in order not to cut or shear them. Silicone rings swell and expand after short contact with petroleum products and certain types of permanent anti-freeze. This causes them to drop out of their cylinder sleeve grooves and their installation in the cylinder block becomes impossible. Do not pre-soak or apply lubricant to a silicone ring until just prior to installation of the cylinder sleeve.

5. Thoroughly clean the packing ring grooves in the cylinder sleeve. Stand sleeve on a clean work bench with packing ring end up. Refer to Figure 9 and install the new black Buna N packing ring in the groove indicated. Install a new red silicone packing ring in each of the other grooves. The silicone rings must be installed dry without lubrication of any kind.

CAUTION: New cylinder sleeve packing rings must be used at each installation of a new or used sleeve.



1. Cylinder Sleeve Flange
2. Buna N (Black) Ring
3. Silicone (Red) Rings

Figure 9. Cylinder Sleeve

6. Brush a light coat of light engine lubricating oil in lower sleeve bore in cylinder block. Be extremely careful so packing rings are not cut on sharp edges of bore in block when installing.

CAUTION: Do not use any other lubricant except light engine oil; doing so prevents proper installation and operation.

7. Using a cylinder sleeve installer (O-ring protector) tool similar to the one illustrated in Figure 10, install cylinder sleeve as follows:

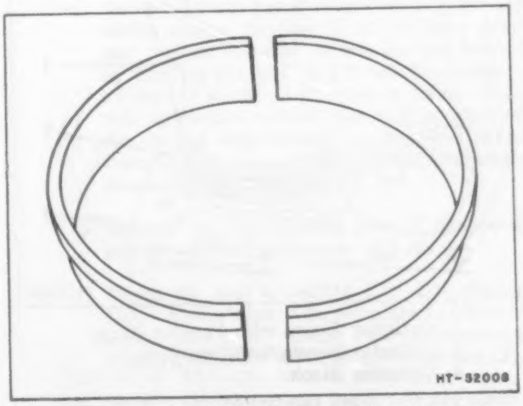
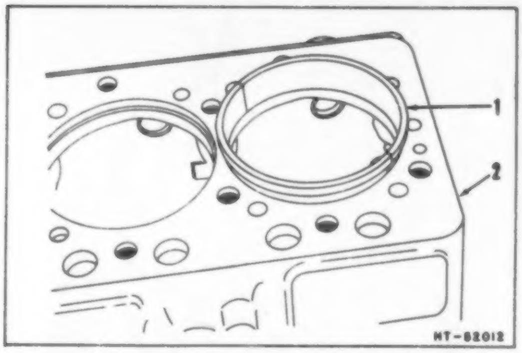


Figure 10. Cylinder Sleeve Installer (O-ring Protector) Tool



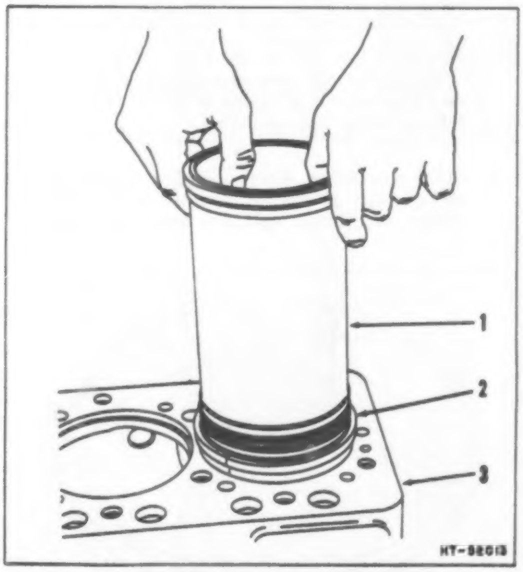
1. Cylinder Sleeve Installer (O-ring Protector) Tool
2. Cylinder Block

Figure 11. Cylinder Sleeve Installer (O-ring Protector) Tool Installed in Cylinder Block

a. Insert cylinder sleeve installer (O-ring protector) tool in cylinder block (Figure 11). Brush I. D. of tool with a light coat of engine lubricating oil.

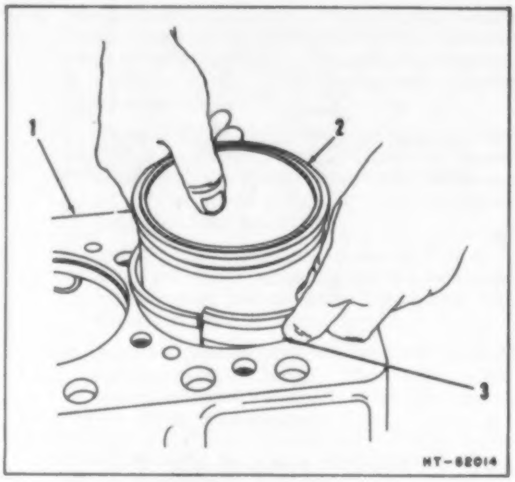
b. Position cylinder sleeve with packing rings in sleeve installer tool.

c. Push cylinder sleeve through installer tool until half or more of the sleeve is inserted into the cylinder block. Hold cylinder sleeve in this position and remove both halves of the installer tool from cylinder block (Figure 13). Carefully force the cylinder sleeve into the sleeve lower bore of the cylinder block.



1. Cylinder Sleeve with Packing Rings
2. Cylinder Sleeve Installer Tool
3. Cylinder Block

Figure 12. Positioning Cylinder Sleeve in Installer Tool



1. Cylinder Block
2. Cylinder Sleeve
3. Half of Installer Tool

Figure 13. Removing Sleeve Installer Tool

C. CYLINDER SLEEVE RESEATING

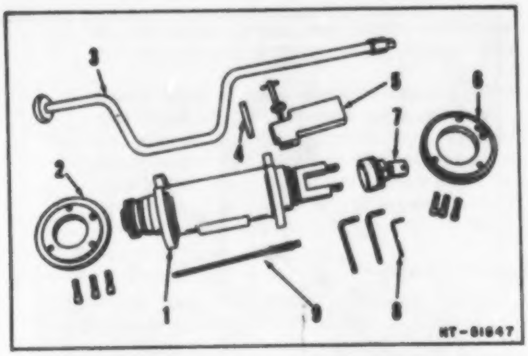
Cylinder sleeve reseating may become necessary if the cylinder sleeves have been allowed to move due to incorrectly torqued cylinder head capscrews, deteriorated head gaskets, or from block counterbore or sleeve flanges eroding from long use. It is important that the cylinder sleeve standout from the top surface of the cylinder block be held between .002" - .005". Variation of more than .003" between adjacent sleeves must not be allowed. Failure to retain specified cylinder sleeve standout will invite premature cylinder head gasket failure. Cylinder sleeve shims are available in .005", .010", .015", and .020" thicknesses to re-establish the specified cylinder sleeve standout.

A cylinder sleeve reseating tool is available; the tool, manufactured by B.K. Sweeney, is discussed in detail below. This tool may be purchased through your local Allis-Chalmers dealer or directly from the B.K. Sweeney Manufacturing Company.

D. CYLINDER SLEEVE RESEATING TOOL

Listed in the steps below are the assembly, installation, and operating instructions for the B.K. Sweeney Counterbore Tool, Model 6091 (Figure 14). The following parts are also required for use with the Model 6091 Tool:

6210-12	Upper Adapter Plate
6210-22	Lower Adapter Plate
621-71	Carboloy Tool Bits (3)
623	Wrench
625	Wrench
626	Speed Handle



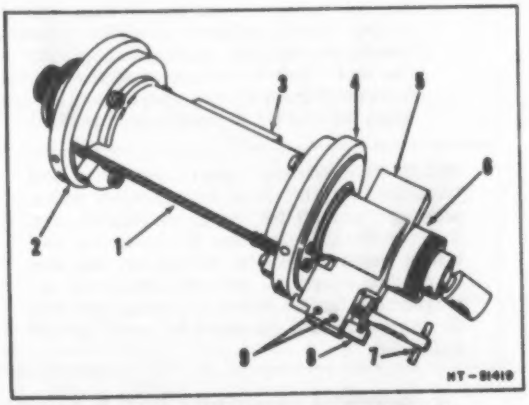
1. Tool Housing
2. Lower Adapter Plate
3. Speed Handle
4. Carboloy Tool Bit
5. Tool Holder
6. Upper Adapter Plate
7. Locking Nut
8. Allen Wrenches
9. Spring Loaded Extension

Figure 14. Cylinder Sleeve Reseating Tool

1. Assembly of Tool.

   a. Install the lower adapter plate with its adjusting screw facing up and positioned in the cutout section of the tool bearing housing (Figure 15).

   b. Install the upper adapter plate to the tool housing so its adjusting screw is facing up and its access hole for installation of the extension for operating the lower adapter plate adjusting setscrew is positioned in line with the lower adjusting screw and in the cutout section of the tool bearing housing.



1. Spring Loaded Extension
2. Lower Adapter Plate
3. Tool Housing
4. Upper Adapter Plate
5. Tool Holder
6. Locking Nut
7. Tool Bit T Handle
8. Tool Bit
9. Setscrews

Figure 15. Cylinder Sleeve Reseating Tool Assembled

   c. Assemble the spring loaded extension between the upper and lower adapter plates (Figure 15).

   d. The tool bearings must be adjusted so no end play exists in the spindle shaft. A small preload is desired. To adjust the bearings to control shaft end play, loosen the setscrew in the bottom knurled nut and tighten the nut by hand to remove shaft end play. Re-tighten setscrew when desired adjustment is obtained.

   e. Install the tool holder and tool bit (Figure 15).

2. Preparation of Cylinder Block for Checking and Reseating Counterbore.

   a. Thoroughly clean the top deck of the cylinder block.

   b. Thoroughly clean upper and lower sleeve bores in cylinder block; remove all scale, rust, and carbon so upper and lower adapter plates and their adjusting pins contact original bore diameters.

CAUTION: Failure to thoroughly clean bores can allow tool to misalign and cut untrue seats.

   c. Measure the present depths of the sleeve counterbores with a depth micrometer at the front and rear of each counterbore, and record. The specified original depth of the counterbore for cylinder sleeve is .315" to .3165".

NOTE: Cylinder block top decks, especially on older engines, are not necessarily square with the sleeve bores.

3. Installation of Tool in Block.

   a. Loosen the two small setscrews (Figure 15) which secure the tool bit in the tool holder and retract the tool bit into the tool holder by turning the tool bit "T" handle counterclockwise as far as possible by hand. This will raise the tool bit to a safe position so its cutting edge cannot be damaged while installing tool assembly in cylinder block sleeve bores.

   b. Retract the centralizing pins in the lower and upper adapter plates.

   c. Insert the tool assembly into the cylinder block so the upper adapter plate is between 1/32" and 1/16" below the counterbore sleeve seat in the block (Figures 16 and 18).

   d. Secure the upper and lower adapter plates in the sleeve bores by tightening the set screws (Figure 17).

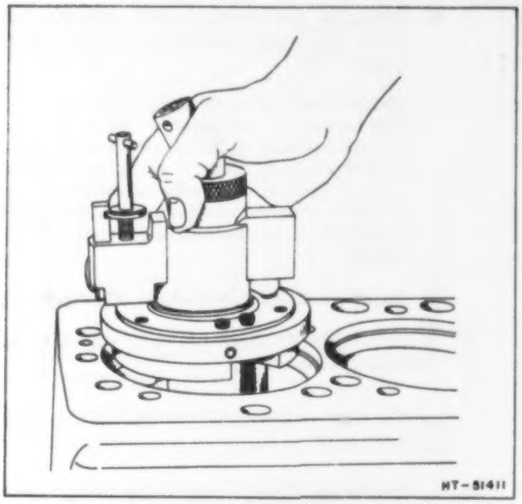
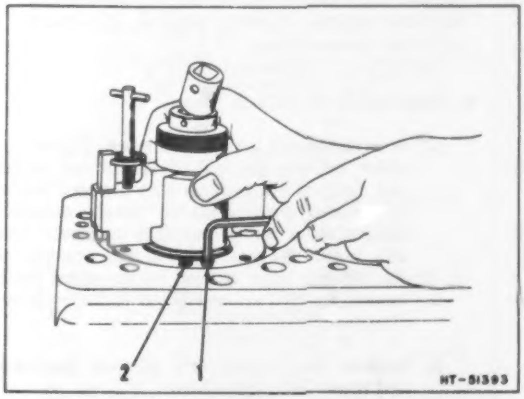


Figure 16. Positioning Cylinder Sleeve Reseating Tool in Cylinder Block

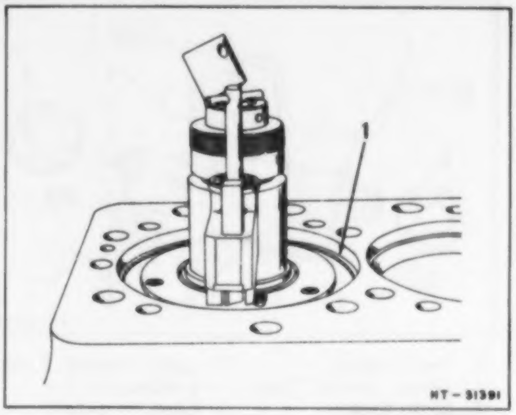
4. Adjusting and Operating Tool.

   a. To adjust the tool for cutting the correct diameter in the counterbore, loosen the knurled nut securing the tool holder. Move the tool holder so the tool bit can be extended into the counterbore about half way. Slide the tool holder until the tool bit just contacts the inside diameter of the counterbore. Tighten the knurled locknut securing the tool holder by hand only. Carefully and slowly turn the tool to be sure the tool bit does not tightly contact the counterbore I. D. at any point in a complete revolution. The specified original counterbore I. D. is 5.006" to 5.011". Readjust tool holder, if necessary, so tool can be revolved easily without excessive contact with counterbore I. D.



1. Setscrew for Securing Lower Adapter Plate
2. Setscrew for Securing Upper Adapter Plate

Figure 17. Securing Cylinder Sleeve Reseating Tool in Cylinder Block



1. Counterbore Sleeve Seat

Figure 18. Cylinder Sleeve Reseating Tool Installed

   b. Lower tool bit until it just contacts the counterbore seat to be cut. Tighten the two small setscrews securing the tool bit (Figure 15).

> CAUTION: Never turn tool counterclockwise; this will damage tool bit cutting edge.

   c. Do not attempt to cut deeper than .001" at a time. Each graduation on tool bit adjusting handle moves the bit approximately .002" on the tool. Loosen and retighten the two setscrews (Figure 15) securing the tool bit each time the tool bit is readjusted for depth.

> NOTE: The cylinder sleeve reseating tool Carboloy tool bit may be replaced with a standard tool bit for rough machining only. For the finish cuts, use the Carboloy tool bit. A regular cylinder boring bar can also be used to rough cut the cast iron to the enlarged bore but the sleeve reseating tool with the Carboloy tool bit must be used for the finish cut.

   d. Determine approximate depth to be cut by checking counterbore depth and sleeve flange thickness with micrometers before starting any cuts. Refer to Item 3, Paragraph B, of this Topic.

e. Insert speed handle and rotate clockwise slowly until tool bit stops cutting (Figure 19).

f. Check depth of recut seat with depth micrometer and calculate desired depth by checking sleeve flange thickness with outside micrometer and selecting desired shims to obtain the specified sleeve protrusion or projection. Cut seat at rate of approximately .001" per cut until calculated desired depth is reached.

CAUTION: When machining new seats, take micrometer readings frequently to prevent the possibility of machining a counterbore too deep.

g. Thoroughly clean cylinder block of all machining chips before attempting to install cylinder sleeves. Install shims as required under sleeve flanges to obtain the specified sleeve protrusion.

NOTE: Do not attempt to measure cylinder sleeve standout with a straight edge and a feeler gauge when a shim is installed in the counterbore because a rough edge or burrs on the shim may give a false reading.

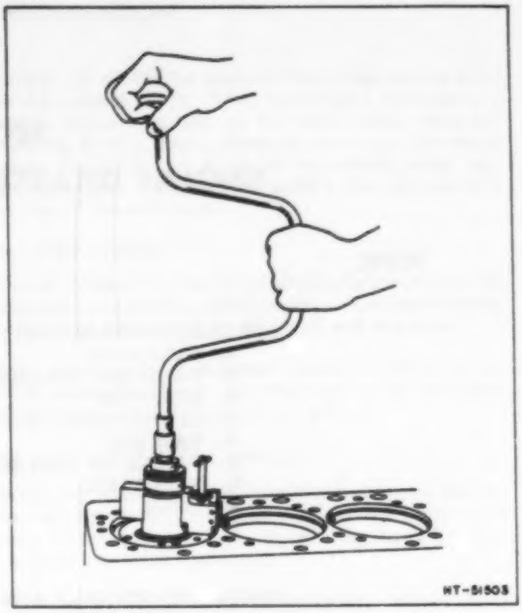


Figure 19. Operating Cylinder Sleeve Reseating Tool

SECTION 15
ENGINE DISASSEMBLY AND ASSEMBLY

TOPIC	TITLE	
1	GENERAL INFORMATION	15.1
	A. CLEANING B. BALL AND ROLLER BEARINGS C. BUSHINGS D. LIP TYPE OIL SEALS E. GASKETS F. PIPING OR TUBING G. FASTENERS H. SHIMS	
2	ENGINE DISASSEMBLY AND ASSEMBLY	15.2
	A. ENGINE DISASSEMBLY B. ENGINE ASSEMBLY C. ENGINE RUN-IN SCHEDULE	

TOPIC 1. GENERAL INFORMATION

This general information will be helpful when disassembling or assembling an engine. It should be read and kept in mind while the work is being performed.

A. CLEANING

After electrical equipment is removed, the exterior of the engine should be thoroughly cleaned, preferably steam cleaned.

A tank of commercial cleaning solvent should be on hand to clean the various engine parts as they are removed from the engine. Some cleaning solvents require that the parts be rinsed in water after cleaning, in this case a tank of warm rinse water should be available. Compressed air should be available to dry parts after they are cleaned.

B. BALL AND ROLLER BEARINGS

After removal, thoroughly clean the bearings in clean solvent and dry with compressed air free of moisture. Inspect bearings to see that they roll freely and are free from cracked, pitted, or worn balls, rollers, and races. Make certain that the shield(s) and the ball retainers are in good condition and are not dented or damaged.

Badly worn ball bearings can be detected by the presence of excessive end play between the outer and inner races. This condition can be detected by holding one race steady and moving the other race endwise, comparing the difference in movement of the races of the used bearing and a new bearing. Check the outer and inner races for indications of bearing creepage. This can be detected by marks on the bearing races or on the bearing area of the bore or shaft where the bearing has been used. Always lubricate a bearing at assembly with clean lubricant. Do not use a bearing which is in bad condition.

After the bearings have been removed, keep the bearings spotlessly clean, well lubricated, and wrap the bearings in clean oil proof paper to prevent the entrance of dirt and rusting. When installing new bearings, do not remove the bearings from package until ready for assembling. Do not wash the lubricant from a new bearing.

Use a press and a suitable sleeve or driver when installing bearings. If these are not available, a cold rolled soft steel rod and hammer may be used to drive the bearings into position; do not strike the bearing shield or ball retainer when installing.

Bearings may be heated to expand the bore, thus facilitating the installation of the bearing on a shaft. One method of transferring heat to bearings is through the use of hot oil. The bearings should never be placed directly on the bottom of a tank or container, but should be suspended in the oil on hooks or placed on a screen so that they may be heated uniformly. A light or medium grade of clean lubricating oil should be used and the temperature must never exceed 300°F. When installing a bearing on a shaft, drive or press on the inner race; when installing it in a bore, drive or press on the outer race. Be careful not to strike the shield, snap ring, ball retainer, or balls when using a rod and hammer to install the bearings.

C. BUSHINGS

Do not remove the bushings for inspection unless the bushings are loose in their bores or are excessively worn, then they must be removed and replaced.

Use a press and a suitable sleeve or driver to install bushings. Ream the bushings to the specified dimensions when reaming is required.

D. LIP TYPE OIL SEALS

When any work has been done which involves the removal of a shaft from an oil seal, or the removal of an oil seal from its bore, the sealing lip of the seal must be carefully examined.

The sealing lip must not be scratched, folded over, torn, or charred from heat. The lip must be flexible and the spring, located inside the lip, must have the proper tension to return the lip to its proper position when the lip is pressed in by hand.

Be sure that the surface of the shaft contacted by the lip of the oil seal is smooth and free from burrs.

When installing an oil seal on a shaft, or a shaft through an oil seal, be sure to protect the sealing lip from damage which might be caused from a keyway, splines, threads, or a hole through the shaft. A small scratch or cut, or a fold in the lip of the seal, will render the seal useless.

Use an oil seal installing bushing, or a thin sheet of stiff paper wrapped around the sharp portion of the shaft, then slide the seal over the bushing or paper.

Use an oil seal installing tool or a press when installing seals into their bores, to prevent damage to the outer case of the seals. If the proper installing tools are not available, a smooth piece of metal or a block of wood can be placed flat against the face of the seal and the seal can be driven into position with a hammer.

When a new oil seal is to be installed, always lubricate the sealing lip before installing.

E. GASKETS

When a gasket is removed, inspect it for damage. If it is in good condition, it can be used again; however, it is recommended to use a new gasket. Make certain the surfaces of the gasket are free from foreign substances and the old gasket particles are removed from the mounting surfaces before a new gasket is installed.

F. PIPING OR TUBING

Tighten fittings only tight enough to prevent leakage. If the fittings are drawn up too tight, damage may result.

Always be sure that the fittings and nuts are clean before tightening.

G. FASTENERS

Keep all nuts, bolts, hose clamps, etc., tight at all times. A periodic check of these fasteners does not take long and may prevent the occurrence of a major failure. Replace any broken or missing capscrews, nuts, or lockwashers.

CAUTION: Capscrews have various grade identification marks and should be installed in their original location. Refer to Paragraph B, FITS AND TOLERANCES AND SPECIFICATIONS Topic in Section 1.

H. SHIMS

Shims should be flat and the surfaces clean and free from foreign substances or corrosion. When removing or adding shims, check the thickness of each shim with a micrometer to obtain accurate adjustments.

TOPIC 2. ENGINE DISASSEMBLY AND ASSEMBLY

A. ENGINE DISASSEMBLY

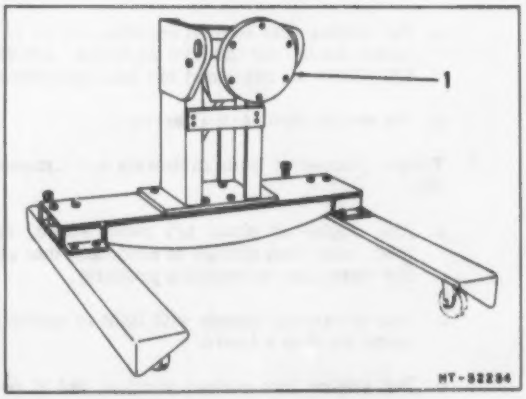
Removal and installation of engine components such as cylinder head, cylinder sleeves, pistons, crankshaft, etc., are covered in the Section of the Manual which pertains to that particular component. The sequence of the order in which they are removed is left to the discretion of the mechanic.

An engine stand (Figure 1) and adapter plate (Figure 2) should be used whenever extensive repair or a complete overhaul of the engine is required. Before the adapter plate can be attached to the engine, remove the following from the left hand side of the engine: air heater solenoid, starter, starter adapter and cables, oil filter elbow and gasket, oil filler hole plate and gasket, fuel pump pad plate and gasket, and oil level gauge and adapter. Also remove any optional equipment that has been attached to the engine in the area where the adapter plate is to be installed. Install the adapter plate with capscrews and washers to the side of the engine cylinder block. While engine is suspended from a suitable hoist or supported on blocks, position engine stand mounting flange with adapter plate. Secure adapter plate to engine stand mounting flange.

An adequate supply of pans or boxes should be available for storage of small parts as they are removed. Parts having machined surfaces which could be damaged should be stored on wooden racks or blocks.

The extent of the work to be done on the engine determines what accessories such as starter, alternator, water pump, hydraulic pump, etc., must be removed. When an engine is to be completely overhauled, all accessories should be removed, disassembled, inspected, and repaired or replaced before they are reinstalled on the engine.

Parts which are identical, such as valves, should be marked or stored in suitable racks so they can be reinstalled in their original position. When shims are removed, tie them together and identify them. Keep them clean and flat until they are reinstalled.



1. Engine Stand Mounting Flange

Figure 1. Basic Engine Stand

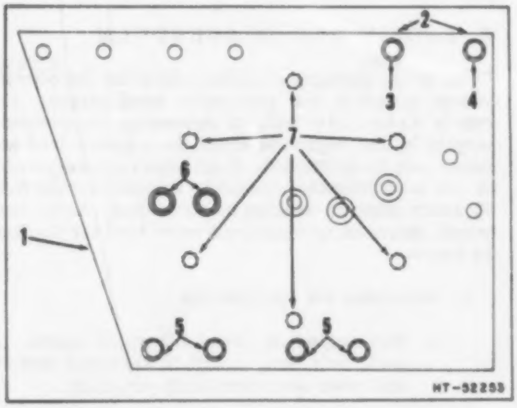
B. ENGINE ASSEMBLY

Removal and installation of engine components such as cylinder heads, cylinder sleeves, pistons, crankshaft, etc., are covered in the Section of the Manual which pertains to that particular component.

The working area where the engine is assembled must be kept as clean as possible. Keeping parts clean before and during assembly cannot be over emphasized. Dirt which enters the engine during assembly will cause abnormal wear and the engine will again need overhaul in a fraction of the time normally expected.

Use of the service tools illustrated in this manual is recommended. Most jobs are accomplished faster and more accurately when the proper tools are used.

Whenever possible, press bushings into position with a press. If it is necessary to use a hammer to install a bushing, use a bushing driver or a suitable bar having a smooth flat end. If a bushing is equipped with an oil hole, make certain the hole is aligned with its corresponding oil supply hole. Always refer to pertinent Sections of this Manual for specific instructions on bushing replacement.



NOTE: Capscrews used must be of Grade 5 classification or better.

1. Engine Stand Adapter Plate
2. Adapter Plate Spacers Location
3. Washer and Capscrew (3/8" - 16 x 2-3/4" lg.)
4. Washer and Capscrew (5/16" - 18 x 2-5/8" lg.)
5. Washers and Capscrews (3/8" - 16 x 1-3/8" lg.)
6. Washers and Capscrews (5/16" - 18 x 7/8" lg.)
7. Tapped Holes (5/8" - 11) - For Mounting Adapter Plate to Engine Stand

Figure 2. Capscrews Location for Mounting Engine Stand Adapter Plate to Cylinder Block

Lubricate ball bearings prior to installation. Lubricate bushings before the shaft is installed. Lubricate the sealing lip of all lip type seals before installing the seal. New seals should be used whenever possible.

New gaskets should be used wherever gaskets are required. New cylinder head gasket MUST be used.

Use capscrews of the correct size, length, and grade classification. Size and length of the various capscrews are listed in the Parts List furnished with the unit. Lockwashers, cotter pins, locking wire, etc., must be used wherever indicated.

A torque indicating wrench is an indispensable tool when assembling the engine. A table of standard torques as well as a list of special torques is furnished in the "FITS AND TOLERANCE AND TORQUE SPECIFICATIONS" Topic in Section 1 of this Manual and should be referred to whenever capscrews or nuts are tightened.

Refer to "VALVE ADJUSTMENT AND CYLINDER HEADS" Topic in Section 1 for cylinder head capscrew torque and torque sequence and for valve lash adjustment.

When filling the engine crankcase, after engine has been overhauled, pour about two quarts of the crankcase lubricant over the rocker arm assemblies and the cylinder head components. This will assure initial lubrication of the valve and push rod mechanism.

C. ENGINE RUN-IN SCHEDULE

Refer to the paragraphs listed below for the correct run-in schedule for particular applications. The run-in schedule will, of necessity, be governed largely by the degree to which the engine's load and speed can be controlled. In all cases prolonged idle or low load operation should be avoided for the first 50 hours after re-ringing or rebuilding. Avoid sustained operation at maximum rated load for the first 24 hours.

1. Generator Set Applications
   a. Run engine at about 1/2 rated speed, no load, only long enough to ascertain that oil and water are circulating properly.

   b. Warm engine up to operating temperature at rated speed, and approximately one quarter load for 1/2 hour maximum.

   c. Run one hour at 40% load.

   d. Increase loads 10% every hour until 90% load is reached.

   e. Put engine to work under normal conditions.

> NOTE: If the normal operation of the generator set is under varying loads, with a load factor of about 50%, and no prolonged full load or no load operation, the engine could be put to work after step c. above.

2. Power Unit Applications
   a. Run engine at about 1/2 rated speed, no load, only long enough to ascertain that oil and water are circulating properly.

   b. Warm engine up at approximately 1/4 load and 2/3 rated speed for 1/2 hour maximum.

   c. Run engine at 1/2 load and 3/4 rated speed for one hour.

   d. Run engine at 2/3 load and 7/8 rated speed for one hour.

   e. Run engine at 3/4 load at rated speed for one hour.

   f. Run engine at 85% to 90% load at rated speed for 1/2 hour.

   g. Put engine to work under normal conditions.

3. Marine Engine Applications
   a. Run engine at about 1/2 rated speed, no load, only long enough to ascertain that oil and water are circulating properly.

   b. Warm engine up at about 1/2 speed with normal propeller load, tied to dock, or 2/3 speed under way.

   c. Run engine one hour at 3/4 speed under way.

   d. Increase rpm in steps of 5% and run one hour each setting until cruising speed (90% of rated rpm) is attained.

   e. Put engine into normal service.

4. Mechanical Transmission Applications
   a. Run engine at about 1/2 rated speed, no load, only long enough to ascertain that oil and water are circulating properly.

   b. Run vehicle empty for two hours under varying load and speed conditions. AVOID LUGGING.

   c. Put engine into normal service, but at reduced loads, for the next 24 hours. AVOID LUGGING or sustained full load operation.

   d. Put engine into normal service.

5. Torque Converter Units In Shovels And Cranes, Etc.
   a. Run engine at about 1/2 rated speed, no load, only long enough to ascertain that oil and water are circulating properly.

   b. Run at varying speeds with light to medium loads for 2 to 4 hours.

   c. Put engine into normal service, but at reduced loads, for the next 24 hours. AVOID LUGGING or sustained full load operation.

   d. Put engine into normal service.

SECTION 16
SERVICE TOOLS

In many cases the use of service tools for disassembly and assembly are required to perform the particular operation and to obtain the best results. The use of service tools enables the serviceman, or mechanic, to perform the operation in the proper manner and in the least amount of time.

The following service tool listing was prepared to assist service and maintenance personnel in the selection of proper tools and combinations of tools to accomplish the various service and maintenance operations described and illustrated in this manual.

The service tools listed below must be ordered directly from the tool manufacturer.

TOOL MANUFACTURERS

(KM)
Kent-Moore Organization, Inc.
Service Tool Division Order Dept.
1501 South Jackson Street
Jackson, Michigan

(OTC)
Owatonna Tool Company
Owatonna, Minnesota

(S)
B.K. Sweeney Mfg. Co.
6300 Stapleton So. Drive
Denver, Colorado 80216

(SO)
Snap-On Tools Corporation
2905 60th Street
Kenosha, Wisconsin

TOPIC	TITLE	
1	LIST OF RECOMMENDED SERVICE TOOLS	16.1

TOPIC 1. LIST OF RECOMMENDED SERVICE TOOLS

Section	Topic	Fig. No.	Manufacturers' Tool Number And Description
1	9	2	(KM) J-6692 Compression Gauge Assembly
			(KM) J-22472 Compression Gauge Adaptor (Less Tip)
			(KM) J-21616 Compression Gauge Adaptor Tip
1	12	11	(KM) J-8689 Nozzle Remover Adaptor
			(KM) J-6471-1 Slide Hammer
1	12	12	(KM) J-8625 Nozzle Tester Set
			(KM) J-6445-50 Spray Collector
			(KM) J-6445-34 Carrying Case For J-8625
1	12	13	(KM) J-6999 Injection Nozzle Holding Fixture
1	12	15	(KM) J-4298-1 Pin Vise
			(KM) J-8537-2 Nozzle Hole Cleaning Wire (3400)
			(KM) J-8537-3 Nozzle Hole Cleaning Wire (3500)
1	12	16	(KM) J-21609-7 Injection Nozzle Bore Cleaner
1	15	2	(KM) J-3172 Feeler Gauge Set
2	5	7	(KM) J-4245 Snap Ring Pliers
2	5	10	(KM) J-22051 Water Pump Coolant Seal Installer
			(KM) J-8092 Seal Installer Handle
2	5	12	(KM) J-22160-2 Water Pump Shaft And Bearing Assembly Installer
2	5	13	(KM) J-22160-1 Water Pump Slinger Positioner
2	5	14	(KM) J-3172 Feeler Gauge Set
4	1	2	(KM) J-6999 Injection Nozzle Holding Fixture
4	3	3	(OTC) 1012-A Gear Puller
			(KM) J-8111-12 Shaft Protector Adapter (Part of Puller Set J-8111)
6	2	28	(KM) J-9495 Mounting Fixture
			(KM) J-9496 Impeller Remover
			(KM) J-9497 Oil Retainer Plate Remover
			(KM) J-9498 Oil Retainer Plate Installer
			(KM) J-9500 Impeller Installer
			(KM) J-9499 Brush, Nylon Bristle
			(KM) J-8873 Snap Ring Pliers
7	3	1	(OTC) AC-525 Cylinder Head Lifting Sling
7	3	4	(KM) J-1264 Torque Wrench (0-200 lbs. ft.)
			(SO) S-8684 Cylinder Head Wrench
7	4	1	(KM) J-8062 Valve Spring Compressor
7	4	2	(KM) J-8056 Valve Spring Testing Tool (Use With Torque Wrench)
7	4	3	(KM) J-5585 Valve Guide Cleaning Tool
7	4	4	(KM) J-269 Valve Guide Remover (Exhaust and Intake)
7	4	5, 6	(KM) J-9317-1 Valve Guide Installer Stop Plate
			(KM) J-9317-4 Valve Guide Installer Pilot
			(KM) J-9317-38 Valve Guide Installer Adapter (Intake)
			(KM) J-9317-39 Valve Guide Installer Adapter (Exhaust)
7	4	9	(KM) J-22463 Insert Reamer Set
			(KM) J-22471 Cutter Head Set
			(KM) J-22470 Arbor (3/8" Diameter)
7	4	10	(KM) J-22290-12 Valve Seat Insert Installer (Intake)
			(KM) J-22290-13 Valve Seat Insert Installer (Exhaust)
			(KM) J-8092 Driver Handle (Valve Seat Insert Installer)
7	4	12, 13, 15	(KM) J-7040 Eccentric Valve Seat Grinder And Dial Gauge
			(KM) J-9296 Valve Seat Grinder Adapter Set
8	1	1	(KM) J-8190 Bar Type Puller
			(KM) J-8180 Puller Legs
			(KM) J-9302 Leg Adapters
			(KM) J-8111-3 Shaft Protector Adapter (Part of Puller Set J-8111)

Section	Topic	Fig. No.	Manufacturers' Tool Number And Description		
8	2	2	(KM)	J-22392	Crankshaft Front Oil Seal Installer
			(KM)	J-8092	Driver Handle (Front Oil Seal Installer)
8	3	3	(KM)	J-6471-10	Idler Gear Shaft Adaptor
			(KM)	J-6471-1	Slide Hammer
9	1	2	(KM)	J-6953	Clutch Pilot Bearing Remover
9	1	3	(KM)	J-5959	Dial Indicator And Attachment Set
9	2	3	(KM)	J-3154-04	Rear Oil Seal Remover And Installer Set
10	3	3	(KM)	J-22393	Oil Pump Drive Gear Remover
10	3	4	(KM)	J-3172	Feeler Gauge Set
11	1	5	(KM)	J-3172	Feeler Gauge Set
11	1	6	(KM)	J-8111	Utility Puller Set
11	1	9	(KM)	J-5959	Dial Indicator And Attachment Set
11	2	2	(KM)	J-22046	Camshaft Bearing Remover And Installer
12	1	1	(KM)	J-4245	Snap Ring Pliers
12	1	2	(KM)	J-8128	Piston Ring Remover And Installer
12	1	3	(KM)	J-7092	Piston Pin Driver
			(KM)	J-1218	Piston Vise
12	1	4, 5, 7	(KM)	J-3172	Feeler Gauge Set
12	1	6	(KM)	J-3272-02	Piston Inserter
13	1	6	(OTC)	PB 24	Pry Bar
13	1	7	(KM)	J-8176	Gear Separator
			(KM)	J-8190	Bar Type Puller
			(KM)	J-8111-3	Shaft Protector Adapter (Part of Puller Set J-8111)
14	2	1	(KM)	J-8060	Cylinder Sleeve Diameter Gauge
14	2	2	(KM)	J-9325	Ridge Reamer
14	2	3	(KM)	J-1918-1	Cylinder Sleeve Remover Bottom Shoe
			(KM)	J-1918-2	Cylinder Sleeve Remover Top Shoe Assembly
			(KM)	J-7108	Slide Hammer Assembly
14	2	10	(KM)	J-22383	Cylinder Sleeve Installer (O-ring Protector)
14	2	14	(S)	Model 6091	B. K. Sweeney Cylinder Sleeve Reseating Tool
			(S)	6210-12	Upper Adapter Plate
			(S)	6210-22	Lower Adapter Plate
			(S)	621-71	Carboloy Tool Bits
			(S)	623	Wrench
			(S)	625	Wrench
			(S)	626	Speed Handle
15	2	1	(KM)	J-6837-01	Basic Engine Stand
15	2	2	(KM)	J-22289-1	Engine Stand Adapter Plate
			(KM)	J-22289-2	Engine Stand Adapter Plate Spacers

TOOLS NOT ILLUSTRATED

(KM)	J-3179	Nozzle Lapping Kit
(KM)	J-5583	Torque Wrench Adaptor (1/2" Female to 3/4" Male)
(KM)	J-5902-01	Cylinder Hone Set
(KM)	J-7125	Carrying Case (For Compression Gauge)
(KM)	J-8166	Hand Tachometer (200 to 2400 rpm)
(KM)	J-9187	Torque Wrench (3/4" Drive, 0 to 300 lbs. ft.)
(KM)	J-22462	Manometer 24"-0-24" Mercury Slack Tube Type
(OTC)	AC-524	Engine Sling

PART III

TWIN DISC POWER TAKE-OFF

(MODEL SP-214-P1)

TWIN DISC POWER TAKE-OFF (MODEL SP-214-P1)

This is a short, simple outline of duties that the owner and operator must perform for long and satisfactory service from this Twin Disc Power Take-off.

ADJUSTMENT

Clutch – If the clutch does not pull, heats, or operating lever jumps out, the clutch must be adjusted. To adjust the clutch, remove the hand hole plate in the housing and turn the clutch until the adjusting lock pin can be reached. Disengage the adjusting lock pin and turn the adjusting yoke or ring to the right, or clockwise, until the operating lever requires a distinct pressure to engage. A new clutch generally requires several adjustments until the friction surfaces are worn in.

Bearings – Ball bearings do not require any adjustment.

The only approved method for the field adjustment of tapered roller bearings in Twin Disc Power-Take-Off Units is by use of a dial indicator to read actual end play.

Adjust tapered roller bearings as follows:

1. Tighten adjusting nut until the shaft requires 60 lbs.-in. to rotate, in addition to seal drag. This step applies before greasing. Mark notch to use.
2. Back-off bearing retainer the number of notches as shown on page 4.
3. Strike output end of shaft with a soft hammer to seat bearing cup (outer race) against bearing retainer. This should give approximately the end play shown on page 4.
4. Measure actual end play with a dial indicator.
5. Adjust bearing retainer until measured end play is within limits given on page 4.
6. Lock bearing retainer.

When taking indicator readings, the indicator should be anchored on the housing and the indicator tip resting on the end (or shoulder) of the shaft. Hold housing firmly and pry shaft axially in and out to get indicator reading.

> Note: It is recommended after a new Power Take-off has been assembled to an engine or the bearings have been adjusted, to rap the shaft on the end to relieve any preloading that may result due to the resistance of the pilot bearing when being pressed into the flywheel.

LUBRICATION

Throwout Collar – Apply a small amount of lubricant once a day, before starting, through the fitting on the tapered part of the housing.

Anti-Friction Bearings – Apply a small amount of lubricant to pilot bearing through hole in the clutch shaft and to shaft bearings through fitting located at the housing hub approximately every 100 hours of operation.

> Note: When a Power Take-off is being used with a direct drive through a flexible coupling, or any other means, thereby making it impossible to get at the fitting in the end of the shaft, provision should be made for cross drilling of the shaft and installing a fitting between the housing and the hub of the driven member.

Lubricant – Use any high grade, high temperature, lithium base gun lubricant for anti-friction bearings, having operating temperatures of 200 ° F.

DRIVING PLATE REPLACEMENT

Common symptoms indicating the driving plate is worn out. The adjusting yoke cannot be screwed up any tighter and, in the case of riveted-on friction discs, that the rivet heads are flush with the face of the disc. In the case of moulded driving plates, the entire plate must be replaced. In the case of driving plates with riveted-on friction disc, the latter may be replaced. Wherever split driving plates are used, these may be replaced by unbolting Power Take-off housing from engine in order to permit getting at the clutch. With solid driving plates, it is necessary to further remove the clutch from the Power Take-off shaft.

REPAIR PARTS

In order to properly identify parts when ordering, always refer to unit and specification number stamped on the pad or plate on the top center of the Power Take-off housing flange.

INSTALLATION

Avoid excessive wear or scrubbing of parts due to misalignment between the engine and the Power Take-off. If wear is experienced check the following:

1. Excessive loads tend to deflect parts to which Power Take-offs are mounted. To determine deflection under actual operating conditions, a dial indicator may be mounted on a rigid part of the engine, such as the crankcase, or independently on the foundation. Readings taken before the drive is installed, with the engine standing still and when under actual operating conditions, will indicate the extent of such deflection. In no case should the indicated deflection exceed .010" at the bearing in the Power Take-off housing.

2. To determine the concentricity of the flywheel housing bore and the alignment of the flywheel housing face, a dial indicator should be used in the manner shown below. All measurements should be taken with the assembled engine mounted on its supports after the flywheel and housing has been thoroughly cleaned.

CHECKING FLYWHEEL HOUSING FACE

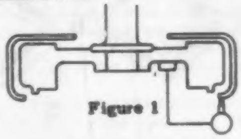


Figure 1

Bolt the indicator to the flywheel so that the indicator is vertical to the housing face and the indicator stem rides on the housing face. (See Fig. 1). Runout should not exceed tolerance listed in table No. 1.

CHECKING FLYWHEEL HOUSING BORE

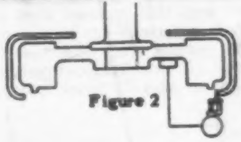


Figure 2

Readjust indicator so that the stem rides on the bore of the flywheel housing. (See Fig. 2) Runout should not exceed tolerances listed in table No. 1.

CHECKING DRIVING RING SURFACE OF FLYWHEEL

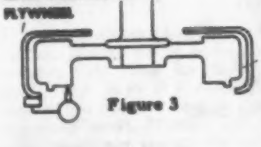


Figure 3

Remove indicator base from flywheel, and bolt indicator to flywheel housing proper, and check flywheel (See Fig. 3)

The variation of the face runout of the surface to which the driving ring or clutch plate is bolted, should not exceed .0005 maximum total indicator reading per inch of diameter.

CHECKING DRIVING RING PILOT BORE OF FLYWHEEL

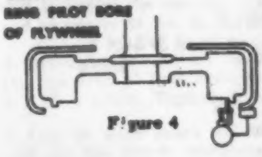


Figure 4

Readjust indicator so that the stem will ride on the driving ring pilot bore. The eccentricity of the driving ring pilot bore should not exceed .005 maximum total indicator reading. Eccentricity between driving ring pilot bore and pilot bearing bore should not exceed .008 total indicator reading.

CHECKING PILOT BEARING BORE OF FLYWHEEL

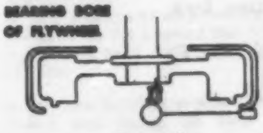
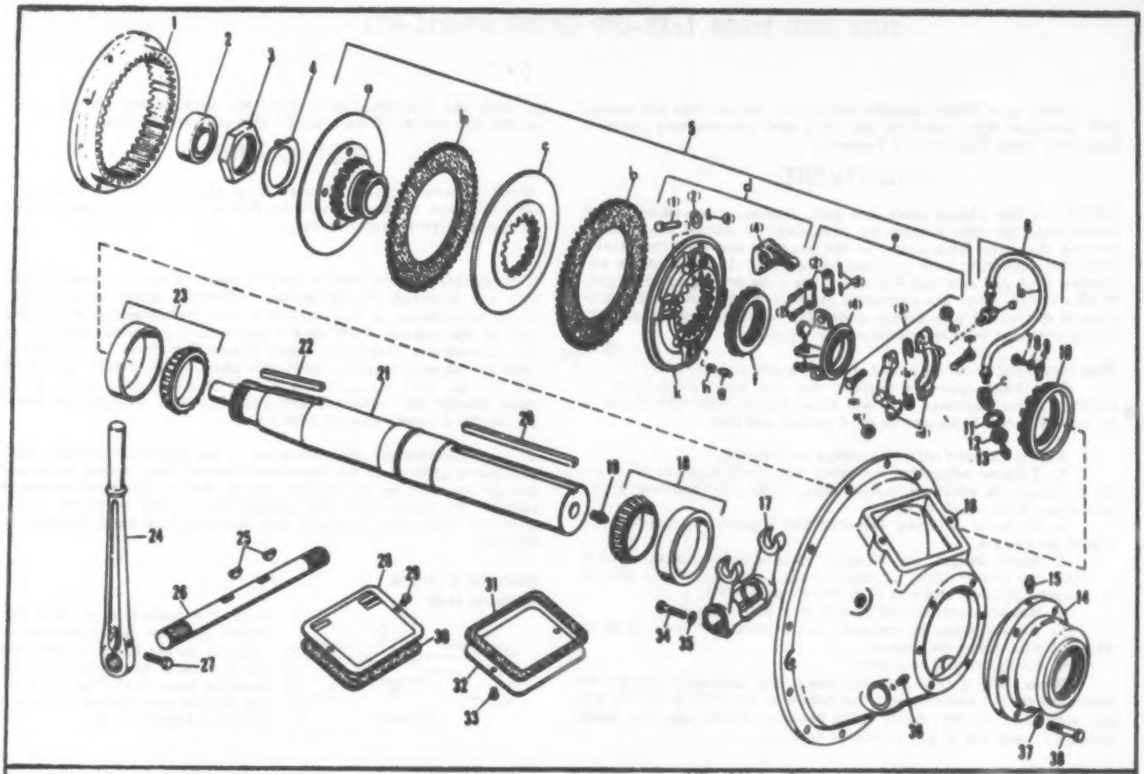


Figure 5

Readjust the indicator so stem rides on the pilot bearing bore cavity. The eccentricity of the pilot bearing bore should not exceed .005 maximum total indicator reading.



Item	Description	Quantity
1	RING, driving	1
2	BALL BEARING, pilot	1
3	NUT, hub hex	1
4	WASHER, lock, hub nut	1
5	CLUTCH ASSEMBLY	1
a	PLATE, hub-and-back	1
b	PLATE, driving	2
c	PLATE, center	1
d	LEVER ASSEMBLY	1
(1)	PIN, headed, lever	4
(2)	WASHER, spring	8
(3)	PIN, cotter	4
(4)	LEVER	4
e	SLEEVE ASSEMBLY	1
(1)	PIN, headed, lever link	8
(2)	LINK, lever	8
(3)	PIN, cotter	8
(4)	SLEEVE, sliding	1
(5)	COLLAR ASSEMBLY	1
(a)	SCREW, cap, hex-head 3/8-24 x 2-1/4	2
(b)	SHIM	2
(c)	NUT, hex 3/8 inch	2
(d)	COLLAR,-split	1
f	RING, adjusting, clutch	1
g	PIN, lock, adjusting, ring	1
h	SPRING, pin, adjusting, lock	1
k	PLATE, floating	1
6	FLEXIBLE HOSE ASSEMBLY	1
a	FITTING, hose	1
b	HOSE	1
c	FITTING, hose	1
7	SCREW, cap, hex-head 5/16-18 x 3/4	1
8	WASHER, lock 5/16 inch	1
9	LOCK, retainer, bearing	1
10	RETAINER, bearing	1
11	WASHER, lock 5/8 inch	1
12	NUT, jam, hex 5/8 inch	1
13	FITTING, hydraulic	1
14	CARRIER, bearing	1
15	FITTING, hydraulic 1/8 inch	1
16	HOUSING, clutch No. 1 SAE	1
17	YOKE, throwout	1
18	TAPERED ROLLER BEARING	1
19	FITTING, hydraulic 1/4 inch	1
20	KEY, shaft 7/8 x 7/8 x 8-3/4	1
21	SHAFT, clutch	1
22	KEY, hub-and-back 1/2 x 3/8 x 4-3/4	1
23	TAPERED ROLLER BEARING	1
24	LEVER, hand	1
25	KEY, Woodruff No. 15	2
26	SHAFT, operating	1
27	SCREW, cap, hex-head 1/2-13 x 1-3/4	1
28	PLATE, cover, instruction	1
29	SCREW, machine, round-head 1/4-20 x 1/2	2
30	GASKET, flat	1
31	GASKET, flat	1
32	PLATE, cover, bottom	1
33	SCREW, machine, round-head 1/4-20 x 1/2	2
34	SCREW, cap, hex-head 3/8-16 x 1-1/2	2
35	WASHER, lock 3/8 inch	2
36	FITTING, hydraulic 1/4 inch	2
37	WASHER, lock 1/2 inch	6
38	SCREW, cap, hex-head 1/2-13 x 2	6

MODEL SP-214-P1 (X-9803) POWER TAKE-OFF

DISASSEMBLY AND ASSEMBLY

REMOVAL AND DISASSEMBLY

1. Remove all attached parts from the output end of the clutch shaft (21). Remove the key (20) and hydraulic (grease) fitting (19) from the output end of the clutch shaft.

2. Remove the twelve hex-head cap screws that secure the clutch housing (16) to the engine flywheel housing. Use two 7/16-14 pusher screws in the tapped holes provided in the clutch housing flange, and remove the power take-off from the engine.

3. Remove the eight hex-head cap screws that secure the driving ring (1) to the engine flywheel. Remove the driving ring.

4. Support the clutch housing on a work bench with wooden blocks. Have the clutch end facing upward.

5. Use a standard bearing puller, and remove the pilot bearing (2) from the clutch shaft.

6. Remove the jam nut (12) and lock washer (11) from the hose fitting (6c) located in the clutch housing (16). Push the fitting and hose into the clutch housing.

7. Straighten the bent portion of the hub nut lock washer (4) from the hub nut (3). Remove the hub nut (3) and the lock washer (4) from the clutch shaft. Discard the hub nut lock washer.

8. Use a conventional gear puller with threaded legs for 5/8-11 tapped holes to pull the clutch assembly (5) from the clutch shaft. Install the puller so the threaded legs screw into the holes provided in the hub-and-back plate (5a) and the jack screw exerts force on the end of the clutch shaft. Remove the shaft key (22). Remove the puller and clutch assembly (5) from the clutch shaft.

9. Set the clutch assembly (5) on a bench with the sliding sleeve assembly end facing upward. Remove the hydraulic (grease) fitting (13) from the hose fitting (6c). Remove the hose fitting (6c) from the hose (6b). Remove the hose (6b) from the hydraulic (grease) fitting (6a). Remove the hydraulic (grease) fitting (6a) from the split collar assembly (5e(5)).

10. Straighten and remove the four cotter pins (5d(3)) from the headed pins (5d(1)). Remove the four headed pins (5d(1)) from the levers and the floating plate. Remove the two spring washers (5d(2)) at each lever location, and remove the levers, sliding sleeve, and collar groups from the floating plate and adjusting ring as an assembly.

11. Straighten and remove the eight cotter pins (5e(3)) from the headed pins (5e(1)). Remove the headed pins (5e(1)), lever links (5e(2)), and levers (5d(4)) from the sliding sleeve assembly.

12. Remove the two nuts (5e(5)(c)) from the two cap screws (5e(5)(a)), retaining the collar to the sliding sleeve. Remove the cap screws, two shims (5e(5)(b)), and the collar halves (5e(5)(d)) from the sliding sleeve.

13. Depress the adjusting lock pin (5g) with a screwdriver, and unscrew the adjusting ring (5f), removing it from the hub of the back plate. Remove the adjusting ring lock pin (5g) and spring (5h) from the floating plate.

14. Remove the floating plate (5k), a driving plate (5b), the center plate (5c), and another driving plate (5b).

15. Turn the clutch housing with attached parts over on the bench, and support the housing with wooden blocks so the output end of the clutch shaft faces up.

16. Remove the six hex-head cap screws (38) and lock washers (37) which secure the bearing carrier (14) to the clutch housing (16).

17. Remove the two round-head machine screws (29) which secure the instruction cover plate (28) and gasket (30) to the housing. Remove the plate and gasket. Discard the gasket.

18. Remove the two round-head machine screws (33) which secure the bottom cover plate (32) and gasket (31) to the housing. Remove the plate and gasket. Discard the gasket.

19. Remove the two hydraulic (grease) fittings (36) from the housing only if replacement of the parts is necessary.

20. Remove the bearing carrier and clutch shaft (21) with attached parts from the housing. Set the clutch shaft with attached parts in a large vise with the clutch end of the shaft facing up. Grip the rear cast section of the bearing carrier with the vise. Remove the hex-head cap screw (7), lock washer (8), and retainer lock (9) from the bearing carrier (14).

21. Remove the bearing retainer (10) from the bearing carrier (14). Lift the clutch shaft (21) separating it with attached parts from the bearing carrier (14). The forward bearing cup (23) will remove with the clutch shaft and bearing cones (23) and (18).

22. Use an arbor press or bearing puller and remove the bearing cones (18) and (23) from the clutch shaft. The bearing cones remove in opposite directions from the shoulder machined on the clutch shaft.

23. Two small (5/16-inch) holes are provided in the bearing carrier for removal of the bearing cup (18). Use a straight blunt punch through these holes and tap the bearing cup out of its bore. Remove the cup only if replacement of the part is necessary. Remove the hydraulic (grease) fitting (15) only if replacement of the part is necessary.

24. Remove the hex-head cap screw (27) that secures the hand lever (24) to the operating shaft (26). Remove the hand lever (24) from the operating shaft.

25. Set the clutch housing on the bench with the clutch end facing upwardly. Remove the two hex-head cap screws (34) and lock washers (35) from the throwout yoke (17). Gently tap one end of the operating shaft (26), and roll out the exposed Woodruff key (25). Repeat this procedure and remove the remaining Woodruff key (25). Remove the operating shaft (26) and throwout yoke (17) from the clutch housing.

ASSEMBLY AND INSTALLATION

1. Install the two 1/4-inch hydraulic (grease) fittings (36) if previously removed.

2. Set the clutch housing on a bench with the clutch end facing up. Install the operating shaft (26) halfway into the clutch housing (16). Slip the throwout yoke (17) onto the operating shaft, and push the shaft through the opening on the other side of the clutch housing. Install one Woodruff key (25) in the operating shaft. Slightly move the throwout yoke on the operating shaft and install the other key. Install the two hex-head cap screws 3/8-16 x 1-1/2 (34) and the 3/8-inch lock washers (35) to secure the throwout yoke (17) to the shaft (26). Tighten cap screws to 38 lbs. ft. torque.

3. Install and secure the hand lever (24) to the operating shaft (on the side of your choice) with a hex-head cap screw (27) 1/2-13 x 1-3/4. Tighten the cap screw to 85 lbs. ft. torque.

4. Use an arbor press and install the two bearing cones (18) (23) on the clutch shaft one from each end with their back faces butting against the stop shoulder on the shaft.

5. Use a piece of steel tubing slightly smaller in diameter than the O.D. of the bearing cup (18) to press the cup into the bearing carrier back face of the cup rearward. Press cup to bottom of bore.

6. Set the bearing carrier (14) in a large bench vise with the clutch end facing up. Grip the casting with the vise jaws below the mounting flange. Install the clutch shaft (21) with

bearing cones into the bearing carrier output end down. Use a piece of steel tubing 18 inches long slightly smaller in O.D. than the bearing cup (23) and install the bearing cup over the clutch shaft and into the bearing carrier. Tap or press the cup into position. Install the bearing retainer (10) into the bearing carrier against the bearing cup (23). Adjust the bearing end play of 0.006-0.010 inch as outlined on page one under "Adjustment." After adjustment, install the retainer lock (9) and secure the lock to the bearing carrier with a lock washer (8) and hex-head cap screw (7) 5/16-18 x 3/4. Tighten the cap screw to 21 lbs. ft. torque.

7. Set the clutch housing (16) on a work bench. Raise and support the housing with wooden blocks about 5 inches from the bench, so the output end of the housing faces up. Install the clutch shaft (21) with attached parts into the clutch housing. Secure the bearing carrier (14) to the clutch housing with six hex-head cap screws (38) 1/2-13 x 2 and six lock washers (37) 1/2 inch. Tighten the cap screws to 85 lbs. ft. torque. Install the hydraulic (grease) fitting (15) if removed previously. Grease fitting is at top position when the unit is in normal operating position.

8. Set the clutch hub-and-back plate assembly on the bench with the hub section facing up.

9. Install a driving plate (5b) onto the hub-and-back plate (5a). Install the center plate (5c) onto the first driving plate. Install the second driving plate (5b). Install the floating plate (5k) upon the second driving plate.

10. Install the adjusting lock pin spring (5h) into the bore provided in the floating plate. Install the adjusting lock pin (5g) and depress the pin and spring with a screwdriver while installing the adjusting ring (5f). Screw ring about half way down hub thread.

11. Install the four levers (5d(4)) and eight lever links (5e(2)) to the lugs on the sliding sleeve with eight headed pins (5e(1)) and eight cotter pins (5e(3)). Spread the ends of the cotter pins.

12. Install the collar halves (5e(5)(d)) and two shims (5e(5)(b)) to the flange provided on the sliding sleeve. Retain the collar to the sleeve with two hex-head cap screws (5e(5)(a)) 3/8-24 x 2-1/4 and two hex-nuts (5e(5)(c)). Tighten the hex nuts to 30 lbs. ft. torque.

13. Install the levers, sliding sleeve, and collar groups as an assembly onto the adjusting ring and floating plate. Retain the levers to the floating plate with eight spring washers (5d(2)) (one on each side of each lever), four headed pins (5d(1)), and four cotter pins (5d(3)). Spread the ends of the cotter pins.

14. Install the hose assembly (6). Install the hose fitting (6a) into the split collar (5e(5)(d)). Install the hose (6b) into the fitting (6a). Install the hose fitting (6c) onto the hose (6b). Install the hydraulic (grease) fitting (13) in the hose fitting (6c).

15. Set the clutch housing (16) with attached parts on the bench with the clutch end facing up and support firmly with wooden blocks.

16. Lower the clutch assembly (5) over the clutch shaft and into the clutch housing, engaging the trunnions on the split collar with the throwout yoke (17). Align the shaft keyway with the keyway in the hub-and-back plate. Install the key (22).

17. Install the hub nut lock washer (4) onto the clutch shaft indexing its lower tab in the spot drilling provided on the hub-and-back plate. Install the hub nut (3). Tighten the nut to remove all clearances between the parts, then tighten the nut 1/6 turn further. Bend the lock washer against a flat on the nut.

18. Route the hose assembly (6) free of moving parts and push the fitting (6c) through the hole provided in the clutch housing. Install the lock washer (11), and install the jam nut (12) to retain the fitting in the housing.

19. Tap or press the pilot bearing (2) on the clutch shaft. Solidly support the output end of the clutch shaft, during installation of the pilot bearing. Also, apply the force to the inner race of the pilot bearing, during installation. Don't press the pilot bearing all the way onto the shaft. Leave a distance of 0.06 inch between the front face of the bearing inner race and the end of the clutch shaft. (See sketch)

20. Adjust the clutch assembly by the following procedure:

(a) With the clutch disengaged, turn the clutch until the adjusting lock pin (5g) can be reached through a hand hole. Depress the pin with a screwdriver and screw the adjusting ring clockwise one or two notches or until a distinct pressure is felt with the hand lever (24).

(b) Release the adjusting pin (5g) and turn the adjusting ring to engage the nearest notch with the pin.

(c) Engage and disengage the clutch a number of times to check the operation. If proper adjustment has not been accomplished, repeat steps (a) and (b) until proper engagement and disengagement is obtained.

21. Place a new instruction cover plate gasket (30) and plate (28) in position on the clutch housing. Secure the plate and gasket with two round-head machine screws (29) 1/4-20 x 1/2. Tighten the screws to 11 lbs. ft. torque.

22. Place a new bottom cover plate (32) and gasket (31) in position on the clutch housing. Secure the plate and gasket to the housing with two round-head machine screws (33) 1/4-20 x 1/2. Tighten the screws to 11 lbs. ft. torque.

23. Position the driving ring (1) against the engine flywheel and secure it with eight hex-head cap screws.

24. Position the P.T.O. clutch housing (16) against the flywheel housing, carefully aligning the pilot bearing (2) with the flywheel pilot and the clutch driving plates (5b) with the driving ring. Secure the clutch housing to the flywheel housing with twelve hex-head cap screws. Rap the output end of the shaft with a soft hammer to relieve any preloading on the bearings.

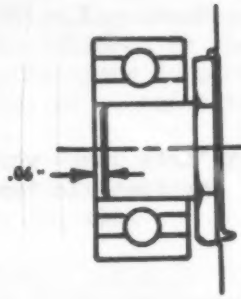
25. Install the 1/4 inch hydraulic (grease) fitting (19) into the output end of the clutch shaft. Install the key (20) 7/8 x 7/8 x 8-3/4 in the clutch shaft, and install all other parts previously removed.

TABLE No. 1 – FLYWHEEL HOUSING TOLERANCES

SAE Housing No.	Face Deviations	Bore Eccentricity
00	.012	.012
0	.010	.010
½	.010	.010
1	.008	.008
2	.008	.008
3	.008	.008
4	.006	.006
5	.006	.006
6	.006	.006

All Figures are Total Indicator Readings Tolerances

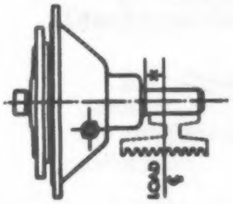
BEARING END CLEARANCE



POWER TAKE-OFF CHART

Model No.	Draw. No.	Main Bearing		Recommended End Play	Notches Backed-Off From Tight
		Manu. No.	T.D. No.		
SP-214-P1	X9803	594-592A	M215	0.006-0.010	2½ - 3½

ALLOWABLE SIDE-PULL LOADS – FOR STANDARD POWER TAKE OFFS



THE FOLLOWING GENERAL FORMULA SHOULD BE USED FOR
FOR DETERMINING THE ACTUAL APPLIED LOAD.

$$L = \frac{126{,}000 \times H.P.}{N \times D} \times F$$

WHERE L = ACTUAL APPLIED LOAD (LBS.)
N = SHAFT SPEED, (REV./MIN.)
D = PITCH DIA. OF SHEAVE, ETC.
* F = LOAD FACTOR

1.0 FOR CHAIN OR GEAR DRIVE
2.5 FOR ALL V-BELT DRIVES
3.5 FOR FLAT BELT

* NOTE: FOR RECIPROCATING COMPRESSORS AND OTHER SEVERE SHOCK DRIVES, MULTIPLY ABOVE FACTORS BY 2.1

		"X" DISTANCE, INCHES (SEE SKETCH)								
PTO	RPM	1	2	3	4	5	6	7	8	9
SP-214-P1 X9803	1000	5980	4700	3880	3290	2870	2540	2270	2060	
	1500	5980	4700	3880	3290	2870	2540	2270	2060	
	2000	5980	4700	3880	3290	2870	2540	2270	2060	
	2200	5980	4700	3880	3290	2870	2540	2270	2060	

APPENDIX A

BASIC ISSUE ITEMS LIST

Section I. INTRODUCTION

1. SCOPE

This appendix lists items which accompany the mixer and elevator or are required for installation, operation, or operator's maintenance.

2. GENERAL

This Basic Issue Items List is divided into the following sections:

a. Basic Issue Items — Section II. A list of items which accompany the mixer and elevator or are required for the installation, operation, or operator's maintenance.

b. Maintenance and Operating Supplies — Section III. Not applicable.

3. EXPLANATION OF COLUMNS

The following provides an explanation of columns in the tabular list of Basic Issue Items, Section II.

a. Source, Maintenance, and Recoverability Codes (SMR).

Column 1:

(1) Source Code, indicates the selection status and source for the listed item. Source codes are:

Code	Explanation
P	Applied to repair parts which are stocked in or supplied from GSA/DSA or Army supply system, and authorized for use at indicated maintenance categories.

(2) Maintenance Code, indicates the lowest category of maintenance authorized to install the listed item. The maintenance level code is:

Code	Explanation
C	Operator/Crew

(3) Recoverability Code, Not applicable.

b. Federal Stock Number, Column 2. This column indicates the Federal stock number for the item.

c. Description, Column 3. This column indicates the Federal item name and any additional description of the item required. A part number or other reference number is followed by the applicable five-digit Federal supply code for manufacturers in parentheses. Repair parts quantities included in kits, sets, and assemblies are shown in front of the repair part name.

d. Unit of Issue, Column 4. This column indicates the unit used as a basis for issue, e.g., EA, PR, FT, YD, etc.

e. Quantity Incorporated in Unit Pack, Column 5. This column indicates the actual quantity contained in the unit pack.

f. Quantity Incorporated in Unit, Column 6. This column indicates the quantity of the item used in the functional group.

g. Quantity Furnished With Equipment, Column 7. This column indicates the quantity of an item furnished with the equipment.

h. Quantity Authorized, Column 8. This column indicates the quantity of an item authorised the operator/crew to have on hand or to obtain as required. As required items are indicated with an asterisk.

i. Illustration, Column 9. This column is divided as follows:

(1) Figure Number, column 9A. Indicates the figure number of the illustration in which the item is shown.

(2) Item Number, column 9B. Indicates the callout number used to reference the item in the illustration.

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SECTION II

BASIC ISSUE ITEMS LIST

(1) SOURCE, MAINT, AND RECOV CODE			(2) FEDERAL STOCK NO.	(3) DESCRIPTION	(4) UNIT OF ISSUE	(5) QTY INC IN UNIT PACK	(6) QTY INC IN UNIT	(7) QTY FURN WITH EQUIP	(8) QTY AUTH	(9) ILLUSTRATION	
(A) S	(B) M	(C) R								(A) FIG NO.	(B) ITEM NO.
				3100 - BASIC ISSUE ITEMS. MANUFACTURER OR DEPOT INSTALLED							
P	C		7520-559-9618	CASE, Operation and Maintenance Manuals	EA			1	1		
P	C		7510-889-3494	BINDER, Looseleaf	EA			1	1		
P	C		7510-244-0359	CONTAINER, PLASTIC: Logbook Binder	EA			1	1		
P	C			DA Technical Manual: TM 5-3895-287-15	EA			1	1		
P	C			DA Lubrication Order: LO 5-3895-287-12	EA			1	1		
P	C		4210-889-2221	EXTINGUISHER, FIRE, Vaporizing Liquid, 1 Quart Size, with Bracket	EA			1	1		

APPENDIX B

MAINTENANCE ALLOCATION CHART

Section I. INTRODUCTION

1. GENERAL

a. This section provides a general explanation of all maintenance and repair functions authorized at various maintenance levels.

b. Section II designates overall responsibility for the performance of maintenance functions on the identified end item or component. The implementation of the maintenance functions upon the end item or component will be consistent with the assigned maintenance functions.

c. No special tools and test equipment required for maintenance functions.

d. Section III contains supplemental instructions, explanatory notes and/or illustrations required for a particular maintenance function.

2. EXPLANATION OF COLUMNS IN SECTION II

a. Group Number, Column 1. The functional group is a numerical group set up on a functional basis. The applicable functional grouping indexes (obtained from TB 750-93-1, Functional Grouping Codes) are listed on the MAC in the appropriate numerical sequence. These indexes are normally set up in accordance with their function and proximity to each other.

b. Functional Group, Column 2. This column contains a brief description of the components of each functional group.

c. Maintenance Functions, Column 3. This column lists the various maintenance functions (A through K) and indicates the lowest maintenance category authorized to perform these functions. The symbol designations for the various maintenance categories are as follows:

C - Operator or crew
O - Organizational maintenance
F - Direct support maintenance
H - General support maintenance
D - Depot maintenance

The maintenance functions are defined as follows:

A - INSPECT. To determine serviceability of an item by comparing its physical, mechanical, and electrical characteristics with established standards.

B - TEST. To verify serviceability and to detect mechanical or electrical failure by use of test equipment.

C - SERVICE. To clean, to preserve, to charge, to paint, and to add fuel, lubricants, cooling agents, and air.

D - ADJUST. To rectify to the extent necessary to bring into proper operating range.

E - ALIGN. To adjust specified variable elements of an item to bring to optimum performance.

F - CALIBRATE. To determine the corrections to be made in the readings of instruments or test equipment used in precise measurement. Consists of the comparison of two instruments, one of which is a certified standard of known accuracy, to detect and adjust any discrepancy in the accuracy of the instrument being compared with the certified standard.

G - INSTALL. To set up for use in an operational environment such as an emplacement, site, or vehicle.

H - REPLACE. To replace unserviceable items with serviceable assemblies, subassemblies or parts.

I - REPAIR. To restore an item to serviceable condition. This includes, but is not limited to, inspection, cleaning, preserving, adjusting, replacing, welding, riveting, and strengthening.

J - OVERHAUL. To restore an item to completely serviceable condition as prescribed by maintenance serviceability standards using the Inspect and Repair Only as Necessary (IROAN) technique.

K - REBUILD. To restore an item to a standard as nearly as possible to original or new condition in appearance, performance, and life expectancy. This is accomplished through complete disassembly of the item, inspection of all parts or components, repair or replacement of worn or unserviceable elements (items) using original manufacturing tolerances and specifications, and subsequent reassembly of the item.

d. Remarks. Column 4. This column is provided for referencing by code the remarks (Section III)pertinent to the maintenance functions.

3. EXPLANATION OF COLUMNS IN SECTION III

a. Reference Code. This column consists of two letters separated by a dash, both of which are references to section II. The first letter references column 5 and the second letter references a maintenance function, column 3, A through K.

b. Remarks. This column lists information pertinent to the maintenance function being performed, as indicated on the MAC, Section II.

SECTION II. MAINTENANCE ALLOCATION CHART

(1) GROUP NO.	(2) FUNCTIONAL GROUP	(3) MAINTENANCE FUNCTIONS A INSPECT	B TEST	C SERVICE	D ADJUST	E ALIGN	F CALIBRATE	G INSTALL	H REPLACE	I REPAIR	J OVERHAUL	K REBUILD	(4) REMARKS
01	**ENGINE**												
0100	Engine Assembly	C	F	C					F	F	D		A
0101	Crankcase, Cylinder Head												
	Crankcase								D	D			
	Head, Cylinder								F	F			
0102	Crankshaft												
	Crankshaft								D	D			B
	Pulley, Damper								F				
0103	Flywheel Assembly												
	Housing								F				
	Flywheel								F	F			C
0104	Pistons, Connecting Rods												
	Pistons, Rings, Pins								D				
	Rods, Bearings								D				
0105	Valves, Camshafts, and Timing System												
	Valves and Idler Gear								H	H			
	Guides, Springs, Locks, Tappets, Push Rods								H				

SECTION II. MAINTENANCE ALLOCATION CHART

(1) GROUP NO.	(2) FUNCTIONAL GROUP	(3) MAINTENANCE FUNCTIONS A INSPECT	B TEST	C SERVICE	D ADJUST	E ALIGN	F CALIBRATE	G INSTALL	H REPLACE	I REPAIR	J OVERHAUL	K REBUILD	(4) REMARKS
0105	Valves, Camshafts, and Timing System (Continued)												
	Rocker Arms				O				H	H			
	Cover								O				
	Camshaft & Timing Gears								D				
0106	Engine Lubrication System												
	Pump, Oil								F	F			
	Filter, Oil			C					O				
	Breather, Crankcase			C					O				
	Lines and Fittings								O				
0108	Manifolds								F				
0109	Accessory Drive Mechanism	C		C					H	H			
02	CLUTCH												
0200	Clutch Assembly			C	O				F	F			
0202	Clutch Release Mechanism												
	Shaft, Yoke. & Bearing			C					F				
	Lever								O				

SECTION II. MAINTENANCE ALLOCATION CHART

(1)	(2)	(3) MAINTENANCE FUNCTIONS											(4)
GROUP NO.	FUNCTIONAL GROUP	A	B	C	D	E	F	G	H	I	J	K	REMARKS
		INSPECT	TEST	SERVICE	ADJUST	ALIGN	CALIBRATE	INSTALL	REPLACE	REPAIR	OVERHAUL	REBUILD	
03	FUEL SYSTEM												
0301	Fuel Injector		O						O	F			D
0302	Fuel Pump												
	Pump, Injection	C	F				H		F	H			
	Pump, Transfer								O	F			
0304	Air Cleaner			C					O				
0306	Tanks, Lines and Fittings												
	Lines and Fittings	C							O				
	Tank, Fuel	C		C					F				
0308	Engine Speed Governor												
	Controls								O				
	Governor				O				O	F			
0309	Fuel Filters			C					O				
0311	Engine Starting Aids								O				
0312	Throttle Controls								O				

SECTION II. MAINTENANCE ALLOCATION CHART

(1)	(2)	(3) MAINTENANCE FUNCTIONS											(4)
GROUP NO.	FUNCTIONAL GROUP	A INSPECT	B TEST	C SERVICE	D ADJUST	E ALIGN	F CALIBRATE	G INSTALL	H REPLACE	I REPAIR	J OVERHAUL	K REBUILD	REMARKS
04	**EXHAUST SYSTEM**												
0401	Muffler and Pipes								O				
05	**COOLING SYSTEM**												
0501	Radiator	C		C					O	F			
0502	Cowling, Deflectors, Shroud								O				
0503	Water Manifold, Header, Thermostat, Housing and Gasket								O				
0504	Water Pump								O	O			
0505	Fan Assembly												
	Fan Assembly and Guard								O				
	V Belt	C			C				O				
06	**ELECTRICAL SYSTEM**												
0601	Generator	C	O		C				O	O			E
0602	Generator Regulator		O		O				O				

SECTION II. MAINTENANCE ALLOCATION CHART

(1) GROUP NO.	(2) FUNCTIONAL GROUP	(3) MAINTENANCE FUNCTIONS A INSPECT	B TEST	C SERVICE	D ADJUST	E ALIGN	F CALIBRATE	G INSTALL	H REPLACE	I REPAIR	J OVERHAUL	K REBUILD	(4) REMARKS
0603	Starting Motor												
	Starter		O	C					O	O			F
	Solenoid		O						O				
0606	Engine Safety												
	Switches								O				
	Governor Overspeed				O				O				
0607	Engine Control Panel												
	Switches, Hourmeter,												
	Lamps								O				
	Panel								F				
	Bulbs								C				
0608	Miscellaneous Items								O				
0609	Lights												
	Light Assembly								O				
	Bulbs								C				
0610	Sending Units, Warning Switches								O				
0612	Batteries	C	O	C					O				

SECTION II. MAINTENANCE ALLOCATION CHART

(1)	(2)	(3) MAINTENANCE FUNCTIONS											(4)
GROUP NO.	FUNCTIONAL GROUP	A INSPECT	B TEST	C SERVICE	D ADJUST	E ALIGN	F CALIBRATE	G INSTALL	H REPLACE	I REPAIR	J OVERHAUL	K REBUILD	REMARKS
0613	Chassis Wiring Harness	C							F	O			
0615	Radio Interference Suppression												
	Capacitors		O						O				G
	Ground Straps	C							O				
08	TRANSFER ASSEMBLY												
0801	Power Transfer Assembly	C		C					F	O			H
09	PROPELLER SHAFTS												
0900	Propeller Shafts												
	Shafts								O				
	Bearings, U-Joints			C					O				
10	FRONT AXLE												
1000	Front Axle Assembly			C					O	O			
11	REAR AXLE												
1100	Rear Axle Assembly					F			F	F			
12	BRAKES												
1201	Handbrakes			C	O				O	O			

SECTION II. MAINTENANCE ALLOCATION CHART

(1) GROUP NO.	(2) FUNCTIONAL GROUP	(3) MAINTENANCE FUNCTIONS A INSPECT	B TEST	C SERVICE	D ADJUST	E ALIGN	F CALIBRATE	G INSTALL	H REPLACE	I REPAIR	J OVERHAUL	K REBUILD	(4) REMARKS
1202	Service Brakes								O	F			
1206	Mechanical Brake System												
	Slack Adjuster				O				O				
1208	Air Brake System												
	Valve, Relay								O	F			
	Chamber, Brake								O	F			
	Filter Assembly			C					O				
	Tank, Reservoir		O	C					O	O			I
1211	Trailer Brake Connections and Controls												
	Hose, Lines and Fittings								O				
13	WHEELS AND TRACKS												
1311	Wheel Assembly												
	Hub Assembly								O	O			
	Bearings			O	O								
1313	Tires, Tubes												
	Tires			C					O				
	Tubes								O	O			

SECTION II. MAINTENANCE ALLOCATION CHART

(1)	(2)	(3) MAINTENANCE FUNCTIONS											(4)
GROUP NO.	FUNCTIONAL GROUP	A INSPECT	B TEST	C SERVICE	D ADJUST	E ALIGN	F CALIBRATE	G INSTALL	H REPLACE	I REPAIR	J OVERHAUL	K REBUILD	REMARKS
15	FRAME												
1501	Frame Assembly												
	Frame								H	O			
	Platform, Walk, Handrail								O	O			
1503	Pintle and Towing Attachments			C					O				
1506	Fifth Wheel												
	Turntable Assembly			C					O	O			
1507	Leveling Jacks			C					O	O			
16	SPRINGS AND SHOCK ABSORBERS												
1601	Springs								H				
1605	Torque Rods				F				F				
18	BODY, CAB, HOOD AND HULL												
1801	Hood, Doors, and Panels								O				

SECTION II. MAINTENANCE ALLOCATION CHART

(1)	(2)	(3) MAINTENANCE FUNCTIONS											(4)
GROUP NO.	FUNCTIONAL GROUP	A INSPECT	B TEST	C SERVICE	D ADJUST	E ALIGN	F CALIBRATE	G INSTALL	H REPLACE	I REPAIR	J OVERHAUL	K REBUILD	REMARKS
1805	Floors								H	F			
1808	Boxes												
	Box, Tool								O				
22	BODY, CHASSIS OR HULL AND ACCESSORY ITEMS												
2202	Accessory Items								O				
2210	Data Plates												
	Plates, Instruction								O				
	Plates, Data								F				
43	HYDRAULIC SYSTEM												
4300	Hydraulic System	C											
4301	Strainers, Filters, Hose, Pipe Fittings and Tubing												
	Strainers and Filters			C					O				
	Lines, Tubing, Pipe and Fittings								O				

SECTION II. MAINTENANCE ALLOCATION CHART

(1)	(2)	(3) MAINTENANCE FUNCTIONS											(4)
		A	B	C	D	E	F	G	H	I	J	K	
GROUP NO.	FUNCTIONAL GROUP	INSPECT	TEST	SERVICE	ADJUST	ALIGN	CALIBRATE	INSTALL	REPLACE	REPAIR	OVERHAUL	REBUILD	REMARKS
4302	Pump and Pump Drives												
	Pump, Hydraulic								O	F			
	Chain, Drive				C				O	O			
	Sprocket			C					O	O			
4305	Control Valves								O	O			
4307	Hydraulic Cylinders								O	F			
4308	Hydraulic Tank	C		C					O				
47	GAGES AND MEASURING DEVICES												
4703	Hourmeter								O				
4705	Flowmeter								O	O			
55	PUMPS												
5500	Pump Assembly	C		C					O	F			
5501	Shafts, Rotors, Impellers								F				
5502	Pistons, Pins, Bearings								F				

SECTION II. MAINTENANCE ALLOCATION CHART

(1) GROUP NO.	(2) FUNCTIONAL GROUP	(3) MAINTENANCE FUNCTIONS A INSPECT	B TEST	C SERVICE	D ADJUST	E ALIGN	F CALIBRATE	G INSTALL	H REPLACE	I REPAIR	J OVERHAUL	K REBUILD	(4) REMARKS
5503	Crankcase								F				
5504	Cylinder, Cylinder Head								F				
5507	Pump Drive												
	Chain				C				O				
	Sprocket Idler			C					O	O			
	Sprocket Pulley								O				
60	**BURNERS**												
6005	Burner Assembly			C					C	O			
6007	Fuel Tank	C	O	C					O	O			J
6010	Exhaust System								O				
73	**ASPHALT EQUIPMENT**												
7300	Bituminous Mixer	C		C									
7303	Controls (Machinery)			C					O				
	Pin, Shear								C				

SECTION II. MAINTENANCE ALLOCATION CHART

(1) GROUP NO.	(2) FUNCTIONAL GROUP	(3) MAINTENANCE FUNCTIONS											(4) REMARKS
		A INSPECT	B TEST	C SERVICE	D ADJUST	E ALIGN	F CALIBRATE	G INSTALL	H REPLACE	I REPAIR	J OVERHAUL	K REBUILD	
7304	Hoppers, Gates, Chutes												
	Hoppers								O				
	Sheaves			C					O	O			
7305	Main Drive												
	Chains				O				O	O			
	Bearings			C					O				
	Housing, Bevel Gear								F				
	Sprockets, Guards, Gears				O				O				
	Clutches								F	F			
7306	Pugmill												
	Bearings			C					O				
	Paddles, Gate Hoist, and Collars								O				
	Gears, Drive								F				
7307	Feeding and Conveyer Frames												
	Frames								F				
	Housing								O				

SECTION II. MAINTENANCE ALLOCATION CHART

(1)	(2)	(3) MAINTENANCE FUNCTIONS											(4)
		A	B	C	D	E	F	G	H	I	J	K	
GROUP NO.	FUNCTIONAL GROUP	INSPECT	TEST	SERVICE	ADJUST	ALIGN	CALIBRATE	INSTALL	REPLACE	REPAIR	OVERHAUL	REBUILD	REMARKS
7309	Vane or Screw Feeders												
	Bearings, U-Joints			C					O				
	Gearcase	C		C					O	F			
	Shafts, Sprockets, Clutch								O				
7310	Pan Feeder												
	Bearing			C					O				
	Chain, Drive			C	O				O	O			
	Guards, Plate, Pan, Shafts								O				
7311	Feeding Shaft												
	Bearings, Clutch			C					O				
	Shaft, Sprocket, Collar								O				
7312	Feeder or Conveyor Discharge												
	Chain				O				O	O			
	Ratchet								O	O			
	Gates, Gage, Sprocket								O				
	Collar								O				
7317	Material Spray Bar												
	Bar, Spray								O				
	Nozzles			C					C				

SECTION II. MAINTENANCE ALLOCATION CHART

(1) GROUP NO.	(2) FUNCTIONAL GROUP	(3) MAINTENANCE FUNCTIONS A INSPECT	B TEST	C SERVICE	D ADJUST	E ALIGN	F CALIBRATE	G INSTALL	H REPLACE	I REPAIR	J OVERHAUL	K REBUILD	(4) REMARKS
7318	Tanks, Valves, Hoses, Lines												
	Tank, Bitumen	C		C					H				
	Strainer			C					O				
	Hose, Lines, and Valves								O				
7319	Water System												
	Strainer			C					O				
	Lines and Fittings								O				
75	CONVEYING: FEEDING												
7501	Belting												
	Scraper				C				O				
	Conveyor Frames								F				
	Guards, Hopper								O				
7503	Drums, Pulleys, Sprockets												
	Drums, Pulleys, Sprockets								O				
	Chain				C				O	O			
	Bearings			C					O				
7504	Rolls												
	Frames, Rollers, Shafts								O				
	Bearings			C					O				

SECTION II. MAINTENANCE ALLOCATION CHART

(1)	(2)	(3) MAINTENANCE FUNCTIONS											(4)
GROUP NO.	FUNCTIONAL GROUP	A INSPECT	B TEST	C SERVICE	D ADJUST	E ALIGN	F CALIBRATE	G INSTALL	H REPLACE	I REPAIR	J OVERHAUL	K REBUILD	REMARKS
	NOTE: The following groups pertain to the elevator only.												
15	**FRAME**												
1503	**Lunette**								O				
75	**CONVEYING: FEEDING**												
7501	**Belting, Chain**												
	Buckets								O				
	Chain								O	O			
	Conveyor Frame								O	O			
7503	**Sprockets**												
	Sprockets and shafts								F				
	Roller and Bearings		C						F				
7506	**Shafts**												
	Bearings		C						F				
	Gear Boxes		C						F	F			
	Shafts								F				

Section III. REMARKS

Reference code	Remarks
A-B	Compression Test
B-I	Metalize, Grind, Align
C-I	Replace Ring Gear
D-B	By Replacement
E-I	Replace Brushes Only
F-I	Replace Brushes Only
G-B	By Replacement
H-I	Gaskets Only
I-I	Welding
I-B	Pressure Test After Repair
J-I	Welding
J-B	Hydrostatic Test After Repair

By Order of the Secretary of the Army:

HAROLD K. JOHNSON,
General, United States Army,
Chief of Staff.

Official:

KENNETH G. WICKHAM,
Major General, United States Army,
The Adjutant General.

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